CZECH ACADEMY OF AGRICULTURAL SCIENCES

Czech Journal of ANIMAL SCIENCE

ŽIVOČIŠNÁ VÝROBA

INSTITUTE OF AGRICULTURAL AND FOOD INFORMATION

9

VOLUME 48
PRAGUE 2003
ISSN 1212-1819

CZECH JOURNAL OF ANIMAL SCIENCE

An international journal published under the auspices of the Czech Academy of Agricultural Sciences and financed by the Ministry of Agriculture of the Czech Republic

For information on Czech J. Anim. Sci. and full papers from Vol. 47 visit http://www.cazv.cz

Aim and scope: The journal publishes scientific papers and reviews dealing with the study of genetics and breeding, physiology, reproduction, nutrition and feeds, technology, ethology and economics of cattle, pig, sheep, goat, poultry, fish and other farm animal management.

The journal is cited in the bibliographical journal Current Contents – Agriculture, Biology and Environmental Sciences and abstracted in Animal Breeding Abstracts. Abstracts from the journal are comprised in the databases: Agris, CAB Abstracts, Current Contents on Diskette – Agriculture, Biology and Envi-ronmental Sciences, Czech Agricultural Bibliography, Food Science and Technology Abstracts, Toxline Plus.

Periodicity: The journal is published monthly (12 issues per year). Volume 48 appearing in 2003.

Acceptance of manuscripts: Two copies of manuscript should be addressed to: Ing. Zdeňka Radošová, Institute of Agricultural and Food Information, Slezská 7, 120 56 Praha 2, Czech Republic, tel.: +420 227 010 352, fax: +420 227 010 116, e-mail: edit@uzpi.cz.

Subscription information: Subscription orders can be entered only by calendar year (January–December) and should be sent to: Institute of Agricultural and Food Information, Slezská 7, 120 56 Praha 2, Czech Republic. Subscription price for 2003 is 1176 CZK or 214 USD.

 MK ČR E 4886

CZECH JOURNAL OF ANIMAL SCIENCE

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POKYNY PRO AUTORY

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Příklady:

Brown J. (1995): Estradiol determination in post-partum sows. J. Endocrinol., *198*, 155–169.

Green K.L., Grey M. (1996): Hormones in milk. J. Anim. Res., *29*, 1559–1571.

Kaláb J. (1995): Changes in milk production during the sexual cycle. In: Hekel K. (ed.): Lactation in Cattle. Academic Press, London. 876–888.

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The influence of chromium supplementation on metabolism, performance and reproduction of dairy cows in a herd with increased occurrence of ketosis

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ABSTRACT: The aim of the experiment was to observe the influence of chromium supplementation in the diet of primiparous cows (heifers) and pluriparous cows (cows) in a herd with increased occurrence of ketosis on metabolism, performance and reproduction. Chromium (chromium chelate – Cr, AGROBAC) was administered in the dose of 5 mg per head/day during the period starting at 4 weeks prior to and ending 3 months after parturition. Blood samples were collected during the last week prior to parturition and during weeks 2, 4, 8 and 12 thereafter. The parameters of reproduction were evaluated on the basis of weekly vaginal, rectal and ultrasonographic examinations. Dietary chromium supplementation did not significantly influence the parameters (glucose, non-esterified fatty acids, β-hydroxybutyrate, total cholesterol, HDL cholesterol, triacylglycerols, bilirubin, aspartate aminotransferase) monitored in the metabolism of dairy cows. A significant difference was found only in the activity of GMT that was higher in the experimental group of animals 1 and 2 months after parturition in primiparous cows. The differences in reproductive functions were not significant either and just a certain trend towards higher conception rates was found in the experimental groups (insemination index 2.1 vs. 2.4 in heifers and 2.0 vs. 2.85 in cows; average number of open days 145 vs. 151 in heifers and 122 vs. 131 in cows). Milk production during the first 100 days of lactation was not influenced significantly. The monitoring of different milk components revealed significantly lower lactose concentrations in heifers from the group with chromium supplementation. Higher fat concentrations were found in the group of cows with dietary chromium supplement during the first month after parturition.

Keywords: cattle; energy metabolism; insemination index; number of open days; milk

Chromium is a trace element necessary for the metabolism of saccharides, lipids and proteins. Some recent experiments showed that the effective form of chromium in the organism is the low-molecular-weight chromium-binding substance (LMWCr), which exhibited direct relations to insulin (Davis and Vincent, 1997). This protein was subsequently named chromodulin (Vincent, 2000) and it was found to potentiate the action of insulin (Lukaski, 1999). Positive influence of chromium in the organism is manifested by improved regulation of glucose uptake by the cells and consequently by better regulation of blood glucose with maximum utilisation of the available sources of energy (Lindemann, 1998).

The symptoms of chromium deficiency are probably related to the interaction between chromium and insulin. The symptoms include impaired tolerance of glucose, increased insulin concentration, glycosuria, poor growth, poor longevity, increased concentration of cholesterol and triacylglycerols, reduced fertility and peripheral neuropathies (Anderson, 1994). Chromium deficiency is manifested especially in the case of metabolic and physi-

Supported by the Grant Agency of the Ministry of Education, Youth and Sports (Grant No. 161700002).

cal stress. Such situations in dairy cows include late pregnancy, parturition and onset of lactation. These periods are of most interest for the research in the effects of chromium supplementation in dairy cows. Although no single conclusion can be drawn from the results of different studies in this area, some of the papers showed that during the above-mentioned periods dietary chromium supplementation shows a positive influence on health status, reproductive functions (Bonomi *et al.*, 1997) and performance of dairy cows (Besong *et al.*, 1996; Hayirli *et al.*, 2001). Different responses to chromium supplementation were found in heifers and cows. Our previous experiment (Pechová *et al.*, 2002) showed a positive influence of supplemental chromium on the metabolism of energy and subsequently on the degree of alterations of liver functions.

The present experiment was designed with the aim to study the influence of supplemental chromium on metabolism, performance and reproduction in dairy cows. We selected a herd with health problems manifested by the occurrence of ketosis during the postparturient period and with subsequent development of the syndrome of excessive lipid mobilisation in dairy cows. The reason for the selection of this herd was to find out whether the positive influence of chromium would be manifested also under the conditions of impaired health status with numerous animals suffering from deficient hormonal regulation in the metabolism of energy.

MATERIAL AND METHODS

The experiment was carried out in the region of Southern Moravia in 2000. The herd was housed on a farm with tied housing for 500 dairy cows. Average lactation of dairy cows was 6 500 litres. The farm suffered from various problems, including insufficient differentiation of feed ration with regard to the performance of the animals, which led to fattening of dairy cows in the second half of the lactation and during the dry period. The syndrome of excessive lipid mobilisation frequently developed after parturition. The experimental animals included 18 heifers in their late pregnancy (heifers) and 30 dairy cows on the second and further lactations (cows). On the basis of analogous pairs the animals were divided into control group (heifers C, $n = 9$; cows C, $n = 15$) and experimental group (heifers E, $n = 9$; cows E, $n = 15$). Chromium was administered in the form of lactate (chromium chelate – Cr, AGROBAC) in the dose of 5 mg per head/day mixed in feeding flour. Chromium supplementation started 4 weeks prior to parturition and finished 3 months after parturition.

During the dry period and during the period of preparation for parturition the animals received the following ration: 12 kg of maize silage, 2 kg of alfalfa haylage, 2 kg of alfalfa hay, 2 kg of barley straw, 13 kg of green clover. Concentrates were fed in the quantity of 3 kg of concentrate mixture and 1 kg of fermented ground wheat during the period of 2 weeks prior to parturition (Table 1).

Table 1. Daily ration for cows 2 weeks prior to parturition

Dry matter	(kg)	14.41
Crude protein	(g)	1 845
Net energy	(MJ)	89.29
Crude fibre	(g)	3 014
Calcium	(g)	119.8
Phosphorus	(g)	52.4
Sodium	(g)	24.02
Potassium	(g)	224.14
Magnesium	(g)	36.94

From the second week after parturition the ration for the dairy cows was changed as follows: 18 kg of maize silage, 8 kg of lucerne haylage, 2.5 kg of lucerne hay, 1.5 kg of protein concentrate, 13 kg of green clover, 2 kg of fermented wheat meal. The compound mixture was added to the ration in the quantity of 4 kg regardless of daily production. From the third week after parturition onwards the quantities of concentrates were differentiated as follows: 4 kg for the milk yield of 25–28 litres, 6 kg for 29–39 litres and 8 kg for the milk yield above 40 litres (Table 2).

Metabolism was monitored in all heifers and in 20 cows on the basis of blood examination. Blood was collected from *v. coccygea* during the last week prior to parturition and subsequently during weeks 2, 4, 8 and 12 in the postparturient period. The following parameters were determined in the serum: non-esterified fatty acids (NEFA), β-hydroxybutyrate (β-HBA), total cholesterol, HDL cholesterol, triacylglycerols (TAG), aspartate aminotransferase

Table 2. Daily ration for dairy cows with milk yield 29–39 litres

Dry matter	(kg)	22.80
Crude protein	(g)	4 190
Net energy	(MJ)	158.35
Crude fibre	(g)	3 770
Calcium	(g)	285.33
Phosphorus	(g)	114.07
Sodium	(g)	47.38
Potassium	(g)	328.14
Magnesium	(g)	69.75

(AST), γ-glutamyl transferase (GMT) and total bilirubin. Glucose concentration was determined from fluoride plasma. The values for different parameters were determined by photometric methods using an automatic analyser Cobas Mira (Roche, Switzerland) and the following tests: total bilirubin (BIL 100, Cat. No. 1105309), triacylglycerols (TGL 4 × 100, Cat. No. 1312983), GMT (GMT KIN 100, Cat. No. 1302082), HDL-cholesterol-precipitation solution (HDL CHOL 250E, Cat. No. 1301302), all supplied by Lachema; glucose (LGlukosa, Cat. No. 11601), total cholesterol (LCholesterol, Cat. No.10851), AST (LAST, Cat. No. 10351) supplied by BioVendor; NEFA (NEFA, Cat. No. FA 115), β-HBA (Ranbut, Cat. No., RB 1008) supplied by Randox.

The assessment of the reproductive status was carried out by rectal palpation, vaginal and ultrasonographic examinations that were carried out from week 2 after parturition in weekly intervals to the confirmation of pregnancy. The following parameters were monitored: occurrence of retained placenta, puerperal endometritis, time to the first detection of corpus luteum (CL) after parturition, number of animals with the first detection of CL later than day 35 after parturition, insemination index, number of open days. Milk yield was evaluated after 100 lactation days on the basis of milk recording data.

The results concerning the metabolism and performance of the animals were statistically evaluated by Wilcoxon's paired test. The parameters of reproduction were evaluated by χ^2-test and Wilcoxon's paired test. The results are shown in tables as mean ± standard deviation. The statistical evaluation was carried out within the framework of MS-Excel® (Microsoft Corp., Inc.).

RESULTS

Metabolism

The results concerning the parameters of energy metabolism, enzyme profile and total bilirubin are shown in Table 3 for primiparous animals and in Table 4 for pluriparous animals.

Primiparous animals. No significant differences were found between the experimental and control groups in a majority of the observed parameters. Energy deficiency and onset of lipid mobilisation were observed in the animals during the periparturient period. This situation continued till week 2 after parturition, when NEFA concentrations elevated above the physiological limit of 0.35 mmol/l (Vrzgula *et al.*, 1990) were found. A higher concentration of β-HBA was found in the animals with chromium supplementation. However, due to high differences between individual animals (coefficient of variation 90% in the experimental group) the difference between the groups was not found significant. Mean blood glucose concentrations did not drop below the physiological values of 3.0–3.9 mmol/l (Vrzgula *et al.*, 1990). In the experimental group glucose concentrations were higher during weeks 2, 4 and 8 after parturition but the results were not significant either due to high individual variability.

An alteration of liver functions was found in a majority of the observed animals. Total bilirubin concentration was elevated above the physiological values of 0.17–5.13 μmol/l (Vrzgula *et al.*, 1990) in both groups of animals during the second week after parturition. In the experimental group the elevated concentrations were already found during the last week prior to parturition. AST showed the increased activity above the physiological value of 1.4 μkat/l (Pechová *et al.*, 1997) almost during the whole period of the experiment. GMT activity was elevated in the samples from almost all collections in the experimental group. The value exceeded the upper physiological limit of 0.52 μkat/l (Pechová *et al.*, 1997) during weeks 4 and 12 after parturition. The results obtained from weeks 4 and 8 after parturition showed a difference that was statistically significant.

Pluriparous animals. No significant differences were found between the experimental and control groups in any of the observed parameters. The nature of metabolic changes in cows was similar to those in heifers with some differences in intensity.

Table 3. Selected metabolic profile parameters in the experimental (E, n = 9) and control group (C, n = 9) in primiparous animals ($x \pm$ SD).

Weeks prior to and after parturition		−1	2	4	8	12
Glucose (mmol/l)	E	3.68 ± 0.17	3.54 ± 1.10	3.34 ± 0.44	3.70 ± 0.55	3.45 ± 0.29
	C	3.60 ± 0.28	3.32 ± 0.65	3.09 ± 0.21	3.36 ± 0.22	3.53 ± 0.34
β-HBA (mmol/l)	E	0.55 ± 0.03	1.31 ± 1.18	0.44 ± 0.15	0.59 ± 0.18	0.49 ± 0.27
	C	0.60 ± 0.18	0.92 ± 0.45	0.43 ± 0.10	0.52 ± 0.19	0.43 ± 0.07
NEFA (mmol/l)	E	0.31 ± 0.20	0.39 ± 0.25	0.14 ± 0.10	0.07 ± 0.03	0.13 ± 0.06
	C	0.29 ± 0.22	0.43 ± 0.21	0.14 ± 0.10	0.11 ± 0.10	0.09 ± 0.08
TAG (mmol/l)	E	0.19 ± 0.07	0.20 ± 0.09	0.21 ± 0.09	0.17 ± 0.06	0.21 ± 0.04
	C	0.25 ± 0.06	0.25 ± 0.08	0.16 ± 0.11	0.13 ± 0.07	0.21 ± 0.04
Total cholesterol (mmol/l)	E	1.69 ± 0.31	1.80 ± 0.57	2.15 ± 0.66	3.78 ± 1.44	3.75 ± 0.73
	C	2.17 ± 0.51	1.79 ± 0.31	2.29 ± 0.38	3.78 ± 0.85	4.32 ± 1.06
HDL-cholesterol (mmol/l)	E	1.39 ± 0.34	1.46 ± 0.41	1.71 ± 0.45	2.63 ± 0.67	3.02 ± 0.78
	C	1.69 ± 0.29	1.35 ± 0.49	1.62 ± 0.57	2.93 ± 0.62	3.33 ± 0.80
Bilirubin (μmol/l)	E	5.48 ± 2.35	6.34 ± 5.16	3.29 ± 1.04	2.18 ± 0.69	2.45 ± 0.92
	C	2.44 ± 1.91	5.89 ± 3.83	3.08 ± 0.63	2.25 ± 0.91	2.00 ± 0.77
AST (μkat/l)	E	1.24 ± 0.09	2.56 ± 1.80	2.29 ± 1.15	1.38 ± 0.69	2.09 ± 1.25
	C	1.53 ± 0.50	1.96 ± 0.72	1.53 ± 0.28	1.52 ± 0.41	1.73 ± 0.78
GMT (μkat/l)	E	0.32 ± 0.04	0.35 ± 0.11	0.65 ± 0.45*	0.48 ± 0.18*	0.53 ± 0.27
	C	0.26 ± 0.04	0.27 ± 0.06	0.29 ± 0.06	0.32 ± 0.04	0.38 ± 0.08

*$P < 0.05$ comparing the experimental and control group

The degree of lipid mobilisation in the observed animals was not high. Increased NEFA concentrations during week 2 after parturition were found especially in the animals of the control group. A marked energy deficiency was found in cows in comparison with heifers, and it was manifested by decreased glucose concentration and increased concentration of ketone bodies especially during week 2 after parturition. These values were not influenced by chromium supplementation.

Alterations of liver functions were detected in almost all animals observed. During week 2 after parturition, the concentrations of total bilirubin increased above physiological values both in the control and experimental group. The elevation of AST activity during week 2 after parturition was very high in both groups. Although these values decreased from week 4 after parturition again, in general the AST activities remained increased in both groups until the end of the period of observation. A more important difference between the experimental and control group was found in the GMT activity that increased above the physiological limit in the experimental group during weeks 4, 8 and 12 after parturition.

The concentrations of total and HDL cholesterol in blood showed similar trends to those in primiparous animals. There was a gradual increase during the whole period of observation. The differences between the experimental and control group were not significant.

Reproduction

The results concerning the parameters of reproduction found during the postparturient period are shown in Table 5. Retained placenta was detected in one heifer in the control group and likewise also in the experimental group. In older cows the same finding was detected in 3 animals in the control group and 4 animals in the experimental group.

Table 4. Selected metabolic profile parameters in the experimental (E, n = 10) and control group (C, n = 10) in pluriparous animals (x ± SD)

Weeks prior to and after parturition		−1	2	4	8	12
Glucose (mmol/l)	E	3.92 ± 0.59	2.71 ± 0.50	3.07 ± 0.66	3.11 ± 0.41	3.49 ± 0.30
	C	3.32 ± 0.23	2.64 ± 0.49	3.12 ± 0.22	3.12 ± 0.28	3.46 ± 0.17
β-HBA (mmol/l)	E	0.65 ± 0.11	1.60 ± 0.78	0.80 ± 0.52	0.74 ± 0.35	0.46 ± 0.19
	C	0.75 ± 0.14	1.74 ± 1.64	0.60 ± 0.14	0.54 ± 0.19	0.45 ± 0.19
NEFA (mmol/l)	E	0.33 ± 0.22	0.33 ± 0.25	0.12 ± 0.06	0.11 ± 0.07	0.09 ± 0.05
	C	0.24 ± 0.17	0.45 ± 0.37	0.11 ± 0.07	0.11 ± 0.09	0.09 ± 0.03
TAG (mmol/l)	E	0.30 ± 0.10	0.20 ± 0.14	0.17 ± 0.08	0.20 ± 0.07	0.24 ± 0.06
	C	0.28 ± 0.11	0.24 ± 0.09	0.14 ± 0.07	0.21 ± 0.09	0.24 ± 0.05
Total cholesterol (mmol/l)	E	1.77 ± 0.36	1.72 ± 0.43	2.82 ± 0.58	4.15 ± 0.95	4.09 ± 0.86
	C	1.97 ± 0.18	1.71 ± 0.54	2.52 ± 0.50	3.95 ± 0.79	4.28 ± 0.73
HDL-cholesterol (mmol/l)	E	1.45 ± 0.29	1.47 ± 0.40	2.10 ± 0.47	3.26 ± 0.72	3.47 ± 0.80
	C	1.61 ± 0.20	1.40 ± 0.46	1.81 ± 0.29	3.20 ± 0.79	3.47 ± 0.68
Bilirubin (μmol/l)	E	4.97 ± 5.21	5.67 ± 2.29	3.40 ± 0.95	2.68 ± 1.03	2.09 ± 0.74
	C	3.39 ± 1.99	6.40 ± 4.37	3.99 ± 1.05	2.54 ± 0.89	2.41 ± 0.74
AST (μkat/l)	E	1.41 ± 0.47	2.84 ± 1.65	1.67 ± 0.80	1.40 ± 0.53	1.73 ± 0.58
	C	1.25 ± 0.30	2.74 ± 1.63	1.78 ± 0.63	1.33 ± 0.36	1.62 ± 0.78
GMT (μkat/l)	E	0.34 ± 0.09	0.33 ± 0.06	0.78 ± 0.56	0.62 ± 0.26	0.58 ± 0.15
	C	0.27 ± 0.07	0.29 ± 0.06	0.52 ± 0.26	0.43 ± 0.11	0.41 ± 0.14

Table 5. Evaluation of reproductive functions in dairy cows in the control (C) and experimental (E) group

	Primiparous animals		Pluriparous animals	
	C	E	C	E
Total number	9	9	15	15
Metritis (cases)	4	5	6	6
Time to the occurrence of first CL after parturition (days)	33.2	40.8	39.5	35.8
Ovarian cysts (cases)	3	2	4	1
Anovulation (cases)	2	0	2	2
Insemination interval (days)	71.6	91.6	77.8	76.4
Insemination index	2.40	2.10	2.85	2.00
Open days (days)	151.1	145.1	130.9	121.9

The occurrence of puerperal complications including metritis requiring therapeutic assistance was similar both in the experimental and control group. Ovarian activity was also monitored. On the basis of mean values, the first corpus luteum (CL) after parturition occurred in heifers of the control group and in cows of the experimental group. After day 35 the first corpus luteum was detected in 25% of heifers in the control group, 50% of heifers in the experimental group, 40% of cows in the control

group and 26.7% of cows in the experimental group. The differences between the groups were not significant.

Mean interval to the first insemination in heifers was 91.6 days in the experimental group and 71.6 days in the control group. In cows the interval was almost identical in the experimental and control group (76.4 vs. 77.8 days). The value of insemination index was lower both in heifers (2.1 vs. 2.4) and in cows (2.0 vs. 2.85) supplemented with chromium. Both the heifers and cows with chromium supplementation had shorter periods of open days (145.1 vs. 151.1 days, and 121.9 vs. 130.9 days, respectively).

Performance

The evaluation of performance of the animals is shown in Table 6. Neither total milk yield for the first 100 days of lactation nor mean values of milk yield during the first month after parturition were significantly influenced by chromium supplementation. Milk lactose concentration was lower in experimental groups both primiparous and pluriparous animals. The values were significantly lower in the primiparous experimental group for 100-day lactation. The concentration of fat in milk was higher in pluriparous animals of the experimental group. A significant difference was found for the first month of lactation. In animals of the experimental groups milk protein concentrations were always lower compared to those of the control group.

DISCUSSION

We did not confirm a positive influence of chromium supplementation on the metabolism of energy in dairy cows from a herd with problematic health status characterised by a high occurrence of ketosis as we did in our previous experiment (Pechová *et al.*, 2002). It can be due to different reasons – the energy metabolism of the animals and the hepatic parenchyma could be impaired more severely but it cannot be ruled out either that the original diet of the animals was sufficiently saturated with chromium without any additional supplementation. No diagnostic methods to determine chromium deficiency in farm animals have been elaborated so far (Anderson, 1998). There is a possibility of employing experimental supplementation of chromium in the herd (Pehrson and Danielsson, 1997) whose results can indicate the status of chromium supply to the animals. Based on this scheme it is possible to conclude that the differences in the results of our two experiments were probably due to the fact that in the present study a sufficient

Table 6. Performance of dairy cows of the experimental (E) and control (C) group during the 1st month of lactation and after 100 days of lactation (x ± SD)

	Primiparous animals		Pluriparous animals	
	C	E	C	E
Total number	9	9	15	15
Last lactation (l)	–	–	6 981 ± 795	6 935 ± 1074
Daily milk yield during 1st month (l/day)	24.6 ± 4.0	26.6 ± 3.6	31.9 ± 5.3	32.0 ± 4.2
Fat (%)	3.24 ± 0.78	3.43 ± 0.77	3.24 ± 0.64	3.84 ± 0.75*
Protein (%)	3.28 ± 0.18	3.07 ± 0.22	3.14 ± 0.22	3.03 ± 0.26
Lactose (%)	5.12 ± 0.10	4.98 ± 0.13	5.03 ± 0.11	4.91 ± 0.18
100 days lactation (l)	2515 ± 380	2569 ± 400	3085 ± 450	3157 ± 389
Daily milk yield (l/day)	25.4 ± 3.9	25.7 ± 3.9	29.5 ± 4.9	30.6 ± 4.7
Fat (%)	3.63 ± 0.39	3.56 ± 0.48	3.72 ± 0.54	3.84 ± 0.80
Protein (%)	3.07 ± 0.22	3.01 ± 0.11	3.03 ± 0.21	2.92 ± 0.20
Lactose (%)	5.04 ± 0.11	4.90 ± 0.13*	4.97 ± 0.14	4.79 ± 0.20

*$P < 0.05$ comparing the experimental and control group

level of chromium intake could have been ensured in the normal diet. It could be a reason why the chromium supplementation did not influence the metabolism of animals during the periparturient period. Another reason could be that the amount of supplemental chromium was low. We chose the dose according to the recommendations of Lyons (1994) 4 mg per head/day in diets for cattle.

Nevertheless, the results of other authors who studied the influence of chromium supplementation on the metabolism of dairy cows showed certain variations as well. Besong *et al.* (1996) found lower values of β-HBA but no differences in glucose or NEFA concentrations. Yang *et al.* (1996) found decreased values for NEFA and β-HBA in primiparous animals. However, no differences were found in pluriparous animals in this study. The next experiment of the same authors with lower level of chromium supplementation showed no differences in NEFA and β-HBA at all. Likewise Ireland (1999) found no decrease in either NEFA or β-HBA in the blood of dairy cows after the administration of chromium. On the contrary, Chang *et al.* (1996) reported a lower occurrence of ketosis in pluriparous animals after chromium supplementation. There is relatively little information in literature concerning the influence of chromium supplementation on the liver. Most of the results are limited to the evaluation of TAG concentration in the liver. Besong (1996) described a decrease of TAG concentration in the liver during the period of chromium supplementation but Hayirli *et al.* (2001), on the contrary, did not find any TAG decrease in the liver of dairy cows during the postparturient period. In our previous experiment (Pechová *et al.*, 2002) we found lower activities of AST, LD and lower bilirubin concentration in dairy cows supplemented with chromium. However, in this study the alteration of liver functions to a lower degree was not found and this was probably due to the fact that the energy metabolism of the animals was not exposed to any positive influence. On the contrary, higher GMT activities were found in dairy cows supplemented with chromium. This could be probably attributed to the hepatotoxic effects of chromium. Toxic effects of chromium on the liver were found in the cases of acute intoxication with hexavalent chromium when hepatic necrosis occurred besides other symptoms (Barceloux, 1999). As trivalent chromium in a relatively low dose was used in our experiment, we think that with regard to the current knowledge of the influence of trivalent chromium on the organism there is a low probability of any toxic effects. There is also another possibility how to explain the obtained results, namely if the metabolism of the animals was impaired in a very serious manner, the supplementation of chromium could not influence the situation at all. As regards the effects of chromium during the postparturient period in dairy cows, the opinions of different authors are contradictory. Some authors reported reduced resistance of insulin (Borgs *et al.*, 1997) but others described its increase (Subityatno *et al.*, 1996). We cannot rule out a possibility that the effects of chromium on metabolism vary in individual dairy cows and that the effects are related to other factors influencing the health status. Relatively high standard deviations suggest high individual variability. A significant difference between the experimental and control group was found in one pair of data from one sampling only.

Other parameters that were studied with regard to chromium included the concentrations of total and HDL cholesterol. The studies in humans showed a decrease in total cholesterol accompanied by a concurrent increase in the proportion of HDL cholesterol (Anderson, 1995). In dairy cows the decrease in total cholesterol concentrations was detected (Pechová *et al.*, 2002) when the elevation exceed the physiological values of 2.5–5.2 mmol/l (Vrzgula *et al.*, 1990). In the present study no influence of chromium supplementation on the concentrations of total and HDL cholesterol was found. At the same time, however, the concentrations of total cholesterol corresponded to physiological values in all animals and the proportion of HDL cholesterol was high during the whole period of study and this can also be a reason why the chromium supplementation showed no effects on these values. The concentrations of HDL cholesterol found in our study are similar to those of Williams (1994). This author also confirmed the effect of dietary fat content on blood cholesterol concentration. Therefore future studies on the influence of chromium on lipid metabolism will have to be designed under the conditions of increased levels of different types of dietary fats.

There have been relatively few studies on the effect of chromium supplementation on reproductive functions so far. In our study we found no positive influence of chromium supplementation on the occurrence of retained placenta or puerperal complications. Contrary to our results, Chang *et al.* (1996) reported a decreased occurrence of endometritis

and retained placenta. Villabolos *et al.* (1997) confirmed a highly positive influence of chromium supplementation on the management of problems with retained placenta. In the animals with chromium supplementation that started 9 weeks prior to the parturition the authors reported almost four times fewer cases of retained placenta compared to the animals without supplementation. As regards the parameters related to conception rate (insemination index, number of open days), although we found a certain trend towards better results in heifers and cows supplemented with chromium, the differences between the groups were not significant. Bonomi *et al.* (1997) carried out a similar study where dairy cows fed a low-chromium diet (0.2 mg/kg of dry matter) were compared with dairy cows supplemented with chromium in the form of yeasts (0.5 and 0.6 mg/kg of dry matter). The results indicated improved reproduction in the following parameters: insemination index (1.5 vs. 2.0 and 2.2), time to first oestrus (41.5 days vs. 47.0 and 49.0 days), time to first insemination (67.5 days vs. 76.0 and 77.0 days), number of open days (84.5 days vs. 103.0 and 105.0 days). Chromium supplementation in this experiment also led to lower occurrence of metritis and ovarian cysts.

It remains unclear whether chromium supplementation can influence the performance of dairy cows. Besong *et al.* (1996) and Bonomi *et al.* (1997) reported increased performance regardless of the age of dairy cows. Yang *et al.* (1996) found an increase of performance by 13% and by 7% in the first and second experiment, respectively, but no influence on the performance of pluriparous animals was confirmed. Subiyatno *et al.* (1996) described an increase in milk yield in primiparous animals by 10% in one experiment, however in another experiment no influence of chromium supplementation on the milk yield was found. Both in our previous study (Pechová *et al.*, 2002) and in the present one the milk yield was not influenced significantly by chromium supplementation. However, the composition of milk was changed. Significantly lower lactose concentrations were detected in primiparous animals of the experimental group. Pluriparous animals showed significantly higher concentrations of milk fat. Lactose content in milk is influenced especially by mastitis, which leads to its dramatic reduction. A slightly reduced lactose concentration can also be found in the case of energy deficiency (Illek and Pechová, 1998). We assume that the reduced values could be caused by ketosis, not by the direct effect of chromium. The composition of milk with regard to chromium supplementation was studied by relatively few authors. In most cases they found no differences between the experimental and control group (Besong *et al.*, 1996, Yang *et al.*, 1996, Šimek *et al.*, 1999). Hayirli *et al.* (2001) reported increased fat production after chromium supplementation, which corresponds to our finding, but contrary to our results the same authors described elevated lactose levels in milk. Bonomi *et al.* (1997) reported an increase in total protein production by 4.7 to 5.0%.

The present experiment was designed with the aim to study the influence of supplemental chromium on metabolism, performance and reproduction of dairy cows in the herd with increased occurrence of ketosis. We did not confirm a positive influence of chromium supplementation on the metabolism of energy in dairy cows. The reproductive functions and milk production during the first 100 days of lactation were not significantly influenced. There were only significant differences in milk components (lactose and fat) between the control and chromium supplemented group.

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Received: 02–12–03
Accepted after corrections: 03–09–18

ABSTRAKT

Vliv suplementace chromu na metabolismus, užitkovost a reprodukci dojnic ve stádě se zvýšeným výskytem ketóz

Cílem pokusu bylo sledování vlivu suplementace chromu u prvotelek a dojnic na druhé a vyšší laktaci (krávy) v chovu se zvýšeným výskytem ketóz na metabolismus, užitkovost a reprodukci. Chrom (chromium chelate – Cr, AGROBAC) byl podáván v dávce 5 mg/kus/den od čtyř týdnů před porodem do tří měsíců po porodu. Odběr krve byl realizován v posledním týdnu před porodem a ve 2., 4., 8. a 12. týdnu po porodu. Reprodukce byla vyhodnocena

na základě výsledků týdenního vaginálního, rektálního a sonografického vyšetření. Supplementace Cr neovlivnila signifikantně sledované parametry (glukóza, neesterifikované mastné kyseliny, β-hydroxybutyrát, celkový cholesterol, HDL-cholesterol, triacylglyceroly, bilirubin, AST) metabolismu dojnic. Signifikantní rozdíl byl zjištěn pouze v aktivitě GMT, která byla první a druhý měsíc po porodu vyšší u pokusné skupiny prvotelek. Rovněž reprodukční funkce nebyly signifikantně ovlivněny. Byla zjištěna pouze tendence zlepšení zabřezávání u pokusných skupin: inseminační index (prvotelky 2,1 vs 2,4, krávy 2,0 vs 2,85), servis perioda (prvotelky 145 vs 151, krávy 122 vs 131). Dojivost za prvních 100 dní laktace nebyla signifikantně ovlivněna. Z jednotlivých složek mléka byla zjištěna signifikantně nižší koncentrace laktózy u suplementovaných prvotelek a vyšší koncentrace tuku u suplementovaných starších krav v prvním měsíci po porodu.

Klíčová slova: skot; energetický metabolismus; inseminační index; servis perioda; mléko

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Digestibility and nutrition value of grass silages

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ABSTRACT: The paper presents the results of metabolic trials on cattle (3 × 4 heifers). Silages for experiments contained 3 grass species: *Festuca arundinacea* (cv. Kora), *Bromus catharticus* Vahl. (cv. Tacit) and *B. festulolium – festucoid* (cv. Hykor). The respective crude protein contents in Hykor, Tacit and Kora were 118.5, 142.1 and 125.9 g/kg DM. Crude protein digestibility was 59.48, 63.73 and 59.82%, respectively. Energy values were determined using prediction equations (1) GE = 0.00588*CP + 0.01918*OM, ME = 0.00137*DCP + 0.01504*DOM (Sommer *et al.*, 1994) and prediction equation (2) GE = 0.0239*CP + 0.0397*F + 0.02*CF + 0.0174*NPEM (Schiemann, 1971); ME = 0.01517*DOM. NEL values according to the 1st equations were 5.65, 5.75 and 5.79 MJ/kg DM, respectively; (2) 5.65, 5.72 and 5.78 MJ/kg DM, respectively. Both compared methods of digestibility evaluation of roughage are comparable.

Keywords: cattle; nutrition of ruminants; digestibility trial; grass silage; energy value of feeds

Detailed information on the content of objectively detectable nutrients in feeds is one of the basic conditions for the application of good nutrition. Grasses and grass silages are important components of feed rations for cattle. Many authors have been concerned with nutrient content in various grass species and cultivars, including generic hybrids. Nutrient contents in 1 kg of dry matter (nutrient concentration) of these fodder crops differ according to the species and cultivar. Fodder grasses are ensiled well and can form a significant part of feed rations as preserved feeds, as described for instance by Braun *et al.* (1996), Míka *et al.* (1998), Pozdíšek and Kohoutek (1998).

Besides the species and cultivar it is also the time of harvest, related to the growth and development of grasses, that has a significant influence on the nutritive value. Pozdíšek and Kohoutek (1998) pointed to the relationship of the content of crude fibre in 1 kg of dry matter and concentration of netto energy in grass silages. The value of correlation index in their paper was 0.931 for NEL and 0.919 for NEV. Pozdíšek *et al.* (1999, 2001, 2002) described the changes in quality and nutrient content in grasses, or grasses and clover, with relation to the time of harvest. Jeangros *et al.* (2002) gave detailed information on the variability of fodder crop quality expressed by the level of organic matter digestibility.

Detailed knowledge of organic matter digestibility, or crude protein digestibility, is very important for expressing the nutritive value of fodder crops (metabolisable energy). It depends on the formulas (prediction equations) used for the calculation of metabolisable energy (ME). Normative equations published by Sommer *et al.* (1994) or Schiemann (1971, cit. Schiemann, 1987) are used for the calculations. ME (MJ) = 0.01517*DOM can be calculated for roughage (AFRC, 1993). The fact that for the calculation of ME it is necessary to know organic matter digestibility (DOM), where an *in vitro* method can be applied, is one of the advantages of this method. Energy requirements of young cattle were studied by Hoffmann *et al.* (1998).

Besides the results of metabolic trials this paper also presents a comparison of the results of energy calculations (GE, ME, NE) in three grass silages (in which digestibility was found out in metabolic trials on heifers).

Supported by the Ministry of Agriculture of the Czech Republic (Grant OD 0176).

MATERIAL AND METHODS

Three species, or more precisely three cultivars of grasses: *Festuca arundinacea* (FA, cv. Kora), *Bromus catharticus* Vahl. (cv. Tacit) and *B. festulolium – festucoid* (FLF, cv. Hykor), were included in the experiment. These grasses were from the first harvest in the period of recommended herbage ripeness, and after a short time they were ensiled into experimental silage pits. Grasses are ensiled well, thus no preservatives were used. We focused on the quality of pressing and covering of the silage pit. At the beginning of the preparatory period, after more than three months of storage, the silage pits were opened and silage samples were analysed by Weenden's method in a laboratory of the Research Institute of Animal Production. When the corrections were carried out, the contents of volatile fatty acids, lactic acid and alcohol were also determined (Vencl, 1985).

The experiments were organized as metabolic trials with the seven-day main period, using one kind of feed and four heifers of average live weight between 215 and 233 kg. Daily intake (kg DM/kg LW): Hykor 0.024, Tacit 0.026, Kora 0.024. The method was in accordance with recommendations for metabolic trials presented by Vencl (1985).

With the use of prediction equations mentioned in the introduction and digestibilities (determined in metabolic trials) we expressed ME, NEL and NEV contents in the tested feeds and the acquired data were statistically evaluated.

In order to express proteins in the PDI system, the degradability values of crude protein (deg) were determined according to the method of Harazim *et al.* (1999). Digestibility values of undegradable crude protein (dsi) were derived from the values of grass silages determined earlier as presented by Sommer *et al.* (1994), Zeman *et al.* (1995), Homolka *et al.* (1996), Petrikovič *et al.* (2000) and others.

Two methods were used for the calculation of energy values. The first method is based on the normative recommendation of Sommer *et al.* (1994) using the equation GE (MJ) = 0.00588*CP + 0.01918*OM for the calculation of gross energy (GE) and ME (MJ) = 0.00137*DCP + 0.01504*DOM for the calculation of metabolisable energy (ME). Crude protein (CP), organic matter (OM), digestible crude protein (DCP) and digestible organic matter (DOM) are in grams per kilogram of dry matter. The second method uses the normative recommendation for GE calculation according to the equation of Schiemann (1971) GE (MJ) = 0.0239*CP + 0.0397*F + 0.02*CF + 0.0174*NPEM, i.e. the values resulting from Weenden's analysis (F = fat, CF = crude fibre, NFE = nitrogen-free extract). ME (MJ) = 0.01517*DOM (AFRC, 1993).

The values of digestibility from metabolic trials in groups of experimental animals and the values of utilisable metabolisable energy (ME), net energy of lactation (NEL) and net energy of fattening (NEF), calculated with the use of prediction equations, were statistically evaluated. Mean statistical characteristics (means, standard deviations and coefficients of variance) were calculated and the values were tested for significance by common statistical methods.

RESULTS AND DISCUSSION

According to the rules for digestibility measurement, samples were taken from grass silages (cvs. Hykor, Tacit and Kora) and analysed by Weenden's method. Furthermore, neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined. Results of the analyses are presented in Table 1. Dry matter corrections were calculated according to the standard (recommendations for metabolic trials). The corrections of the values were carried out with the use of dry matter increase coefficients (1.025, 1.059, 1.014) for the above-mentioned grass silages. The final data after the correction for volatile substances (VS) are also presented in Table 1. Grass silages of Hykor and Kora cultivars show similar contents of acquired indicators (see Table 1). In comparison with these silages cv. Tacit had a higher content of nitrogen and a lower content of fibre. On the other hand, a higher content of ash was determined.

Table 2 shows the values of digestibility. According to the recommendations for metabolic trials we can state that the variability of dry matter digestibility coefficients was lower in each metabolic trial than the required value (1.5, in DOM over 50%). Statistically significant differences in DCP were determined in connection with the detected CP contents in the evaluated grass silages. A significant difference in lower digestibility of cv. Hykor in comparison with the other cultivars was detected when fibre digestibility coefficients are concerned (Table 2). As shown in Table 3, the difference was also significant in metabolisable energy (m) and net energy concentration.

Table 1. Analysis of grass silages for metabolic trials

Cultivars	Hykor		Tacit		Kora	
	without cor.	after cor.	without cor.	after cor.	without cor.	after cor.
FM (g/kg)	416.8	427.3	298.4	316.0	469.8	476.5
DM (g/kg)	1 000.0	1 000.0	1 000.0	1 000.0	1 000.0	1 000.0
CP (g/kg DM)	121.5	118.5	150.5	142.1	127.7	125.9
F (g/kg DM)	34.6	33.8	40.1	37.9	36.1	35.6
CF (g/kg DM)	268.5	261.9	231.6	218.7	259.6	256.0
NFE (g/kg DM)	463.6	477.4	426.0	458.0	462.7	470.2
A (g/kg DM)	111.1	108.4	151.8	143.3	113.9	112.3
OM (g/kg DM)	888.2	891.6	848.2	856.7	886.1	887.7
NDF (g/kg DM)	542.1	528.9	442.2	417.6	537.1	529.7
ADF (g/kg DM)	316.3	308.6	299.9	283.2	320.8	316.4

DM = dry matter, FM = fresh matter, cor. = correction for VS, VS = volatile substances, CP = crude protein, F = fat, CF = crude fibre, NFE = nitrogen-free extract, A = ash, OM = organic matter, NDF = neutral detergent fibre, ADF = acidic detergent fibre

Table 2. Digestibility, nitrogen retention and degradability of three grass silages

Cultivars	Hykor			Tacit			Kora		
Units	AVG	Sx	V	AVG	Sx	V	AVG	Sx	V
CP (%)	59.48^{T}	1.17	1.97	$63.73^{H,K}$	0.68	1.07	59.82^{T}	0.54	0.91
F (%)	58.77	2.58	4.40	59.85	0.69	1.15	59.55	1.25	2.11
CF (%)	$74.00^{t,k}$	2.26	3.06	78.88^{h}	2.01	2.55	78.66^{h}	1.05	1.34
NFE (%)	72.15^{T}	1.03	1.43	75.72^{H}	1.02	1.35	72.95	1.74	2.39
A (%)	43.54	2.00	4.58	42.86	0.69	1.61	42.61	1.27	2.99
OM (%)	70.50^{T}	1.04	1.47	$73.84^{H,k}$	0.45	0.61	72.20^{t}	0.71	0.98
NDF (%)	$74.63^{T,K}$	1.97	2.63	$80.87^{H,K}$	0.61	0.76	$78.75^{H,T}$	0.48	0.61
ADF (%)	$69.92^{T,K}$	1.36	1.94	74.95^{H}	1.45	1.94	74.60^{H}	1.58	2.12
Ret. N (g/kg DM)	3.11	0.19	6.11	5.41	0.23	4.25	5.16	0.27	5.20
Deg (%)	72.80	0.00	0.00	77.60	0.00	0.00	73.80	0.00	0.00
Dsi (%)	66.00	0.00	0.00	69.00	0.00	0.00	66.00	0.00	0.00

CP = crude protein, F = fat, CF = crude fibre, NFE = nitrogen-free extract, A = ash, OM = organic matter, NDF = neutral detergent fibre, ADF = acid detergent fibre, Ret. N = nitrogen retention, Deg = degradability value of CP, Dsi = digestibility value of undegradable CP

$^{H,T,K}P < 0.01$, $^{h,t,k}P < 0.05$

Comparing the energy values of feeds in the first and second part of Table 3 with the application of different methods for GE and ME calculations, it can be stated that no statistically significant differences in the results of energy contents (NEL and NEF) were found out. For the level of energy metabolism (m) 0.548 there is a certain tendency of higher values, with the application of prediction

Table 3. Nutritive value of three grass silages

Cultivars	Hykor			Tacit			Kora		
Units	AVG	Sx	V	AVG	Sx	V	AVG	Sx	V
1st prediction equation (according to Sommer *et al.*, 1994)									
GE (MJ/kg DM)	17.80	0.00	0.00	17.27	0.00	0.00	17.77	0.00	0.00
m (ME/GE)	0.537^{T}	0.008	1.448	$0.558^{H,k}$	0.003	0.610	0.548^{t}	0.005	0.984
ME (MJ/kg DM)	9.55	0.14	1.45	9.64	0.06	0.61	9.74	0.10	0.98
NEL (MJ/kg DM)	5.65	0.10	1.76	5.75	0.04	0.70	5.79	0.07	1.20
NEF (MJ/kg DM)	5.53^{t}	0.13	2.27	5.71^{h}	0.05	0.95	5.71	0.09	1.54
2nd prediction equation (according to Schiemann, 1971)									
GE (MJ/kg DM)	17.72	0.00	0.00	17.24	0.00	0.00	17.72	0.00	0.00
m (ME/GE)	0.538^{T}	0.008	1.471	0.556^{H}	0.003	0.606	0.549	0.005	0.985
ME (MJ/kg DM)	9.54	0.14	1.47	9.60	0.06	0.61	9.72	0.10	0.98
NEL (MJ/kg DM)	5.65	0.10	1.79	5.72	0.04	0.74	5.78	0.07	1.20
NEF (MJ/kg DM)	5.53	0.13	2.30	5.67	0.05	0.95	5.70	0.09	1.54
UDP (g/kg DM)	32.23	0.00	0.00	31.83	0.00	0.00	32.99	0.00	0.00
PDIA (g/kg DM)	23.61	0.00	0.00	24.38	0.00	0.00	24.17	0.00	0.00
PDIN (g/kg DM)	71.26	0.00	0.00	85.88	0.00	0.00	75.59	0.00	0.00
PDIE (g/kg DM)	75.49^{k}	0.86	1.14	76.29	0.36	0.47	76.94^{h}	0.59	0.76

GE = gross energy, ME = metabolisable energy, m = ME/GE
NEL = net energy of lactation, NEF = net energy of fattening
UDP = undegradable protein, PDI = proteins digestible in the intestine (N = nitrogen, E = energy)
$^{H,T,K}P < 0.01$, $^{h,t,k}P < 0.05$

equations in the first part of Table 3 (calculations according to Sommer *et al.*, 1994). With regard to the magnitude of difference and level of energy metabolism (from which the differences start to be significant), both methods of statistical evaluation of roughage are comparable in their practical use.

On the basis of the results of nitrogen evaluation in a PDI (proteins digestible in the intestine) system, differences between the PDIN (nitrogen) and PDIE (energy) ratios in tested feeds were found out. With regard to the use of detected degradability values according to feeds it was impossible to test the differences between UDP (undegradable protein), PDIA and PDIN values statistically. In PDI values, with digestibility values determined in experimental animals, the acquired values were tested. In nutrients characterising the "nitrogenous part" of the nutritive value of tested feeds a gradual decrease was observed in both forms of proteins digestible in the intestine (PDIN and PDIE) with an increase in fibre content and decrease in crude protein content in feeds. A steep decrease in PDIN concentration is related to a fast decrease in crude protein content during the vegetation period as opposed to a slow decrease in the content of fermentable organic matter in dry matter and thus a slow decrease in PDIE concentration on later dates of the first harvest. With the applied level of nitrogen fertilization of 120 kg (60 + 60 kg N/ha) the PDIN and PDIE concentrations were lower in metabolic trials in the harvests around 20 May. In the following period a higher PDIE concentration was detected.

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Received: 02–12–12
Accepted after corrections: 03–09–18

ABSTRAKT

Stravitelnost a výživná hodnota travních siláží

V článku jsou uvedeny výsledky tří bilancí na skotu (jalovicích). Pro provedení bilancí byly vyrobeny siláže ze tří druhů trav: *Festuca arundinacea* (FA, cv. Kora), *Bromus catharticus* Vahl. (cv. Tacit) a *B. festulolium – festucoid* (FLF, cv. Hykor). Obsah dusíkatých látek v 1 kg sušiny (Hykor 118,5 g, Tacit 142,1 g a Kora 125,9 g); hrubé vlákniny (261,9 g, 218,7 g, 256,0 g); NDF (528,9 g, 417,6 g, 529,7 g,) a ADF (308,6 g, 283,2 g a 316,4 g). Pokusy byly organizovány jako klasické bilance se sedmidenním hlavním obdobím, při použití jednoho krmiva u čtyř jalovic

(minimálně tři vyhodnotitelné) o průměrné živé hmotnosti 215 až 233 kg. Stravitelnost dusíkatých látek (59,48 %, 63,73 % a 59,82 %); organické hmoty (70,50 %, 73,84 % a 72,20 %); NDF (74,63 %, 80,87 % a 78,75 %). Energetické hodnoty byly počítány jednak při uplatnění predikčních rovnic (1) BE = 0,00588*CP + 0,01918*OM, ME = 0,00137*DCP + 0,01504*DOM (Sommer *et al.*, 1994) a predikčních rovnic (2) BE = 0,0239*CP + 0,0397*F + 0,02*CF + 0,0174*NPEM (Schieman, 1971), ME (MJ) = 0,01517*DOM (AFRC, 1993). Hodnoty NEL v kg sušiny 1. rovnice (5,65 MJ, 5,75 MJ a 5,79 MJ), resp.; podle 2. rovnice (5,65 MJ, 5,72 MJ a 5,78 MJ). Vzhledem k velikosti rozdílu a úrovni metabolizovatelnosti energie, od které se rozdíly začínají projevovat, je možné konstatovat, že pro praktické využití jsou oba porovnávané postupy energetického hodnocení objemných krmiv ve svých výsledcích srovnatelné.

Klíčová slova: skot; výživa přežvýkavců; bilanční stravitelnost; travní siláže; energetická hodnota krmiv

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The effect of palmitic acid fortified maize wet milling by-product on the performance of weaner rabbits

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ABSTRACT: A 6-week experiment was carried out to determine the effect of palmitic acid fortified maize wet milling by-product on the performance of weaner rabbits. Forty-eight weaner rabbits (New Zealand White and Dutch breeds) were assigned to four dietary treatments of 0%, 25%, 30% and 50% levels of the palmitic acid fortified maize wet milling by-product. The four treatments were replicated three times with 4 weaner rabbits per replication. The maize by-product was dried to a moisture content of 8% and added 2 litres of ungraded palmitic acid bought on the market to 100 kg of the maize by-product and dried again to a moisture content of 6% and used to formulate experimental diets: 0% diet (control) contains no maize wet milling by-product, 25% diet contains 25% of the by-product replacing maize, 30% and 50% diets contain 30% and 50% of the by-product replacing maize, respectively. Each of the experimental diets was randomly assigned to a group of 12 weaner rabbits with 4 rabbits per replication and fed for 6 weeks (42 days). Data were collected on feed intake, growth rate, feed conversion ratio. The analysis of the data indicated that there were no significant differences ($P > 0.05$) in growth rate, feed intake and feed conversion ratio between the control receiving 0% palmitic acid fortified maize wet milling by-product and the 25%, 30% and 50% treatment levels. However, the optimal performance of rabbits at 30% and 25% levels of the by-product was higher ($P < 0.05$) than the other experimental levels. The results of dressing percentage indicated that there were no significant differences ($P > 0.05$) in the lumbar region, breast weight, however, there were differences $P < 0.05$ in the viscera weight in rabbits receiving the 30% and 25% levels of the by-product. Costs of production were highly reduced by the replacement.

Keywords: palmitic acid; maize wet milling by-product; weaner rabbits

The average Nigeria gets only a quarter of the minimum daily protein requirement (Oyenuga, 1975). The situation is becoming worse and most people in developing countries continue to suffer from nutritional deficiencies as a result of inability to harness and utilize the available resources at their disposal for the production of the much needed animal protein (Tegbe, 1985).

Domestic rabbits can very well become the most important livestock species of focus as a possible solution to the subsequent very low per capita animal intake in the third world countries. The rabbit is extremely prolific, producing offspring more regularly than any other animal. It exhibits a fast rate of growth and has a high degree of genetic diversity.

Rabbits utilize waste products more effectively thus offering an alternative to other producing species for the improvement of protein supply to the human population and the realization of monetary income by putting into effective use the waste materials that are inedible for humans (Schlolaut, 1985).

Agro-industrial by-products have been identified as alternative feedstuffs. Maize wet milling by-products were found to contain a reasonable amount of nutrients that are utilizable by the livestock (Longe and Olonilua, 1977).

This paper reports on the performance of weaner rabbits fed conventional concentrate diets partially replaced by palmitic acid fortified maize wet milling by-products.

MATERIAL AND METHODS

The experiment was carried out in the Imo State University Owerri. Imo State is in the south-eastern agro-ecological zone of Nigeria. The climatic data of Owerri were summarized by the Ministry of Lands and Surveys Atlas of Imo State (1984).

Owerri is at the altitude of 90 m west, the mean annual rainfall, temperature and humidity are 2 500 mm, 26.5–27.5°C and 70–80%, respectively. The soil is sandy loam with average pH 5.5.

The maize wet milling by-product was collected from the women who are commercial producers of Ogi. The by-products are sun dried to a moisture content of 8% before 4 litres of ungraded (raw) palmitic acid are mixed with it at a ratio of 4 litres: 100 kg and sun dried again. Samples of maize by-products were analysed for proximate composition to determine: dry matter, crude protein, crude fibre, ether extract, ash and then the nitrogen free extractive value according to AOAC (1995).

Experimental diets

Four experimental diets were formulated; Diet 1 (the control) was a conventional concentrate diet for rabbits, Diet 2 consisted of 25% replacement of maize by the palmitic acid fortified maize by-product, Diet 3 consisted of 30% of the maize by-product fortified with palmitic acid and Diet 4 contained 50% of the maize by-product. The composition of the particular diets is shown in Table 1.

Experimental animals and design

Forty-eight (48) weaner rabbits (24 males and 24 females) of the New Zealand White and Dutch breeds were selected; they weighed 468 ± 1 grams on average. They were divided into four groups of 12 rabbits each (6 females and 6 males) and were later replicated 3 times of 4 rabbits per replication

Table 1. Ingredient and chemical composition of experimental diets

Ingredients	Control	Diet 2	Diet 3	Diet 4
	0%	25%	30%	50%
Maize	60	35	30	10
Palmitic acid fortified maize wet milling by-product	–	25	30	50
Soybean meal	15	15	15	15
Palm kernel cake	7	7	7	7
Wheat offal	10	10	10	10
Blood meal	4	4	4	4
Bone meal	3.5	3.5	3.5	3.5
Vitamin/mineral premix	0.25	0.25	0.25	0.25
Common salt	0.25	0.25	0.25	0.25
Calculated chemical composition (%DM)				
Crude protein	18.54	18.60	18.62	18.67
Crude fibre	4.87	7.25	7.46	7.68
Ether extract	4.01	9.87	10.18	10.37
Calcium	1.35	1.70	1.73	1.78
Phosphorus	0.96	0.92	0.93	0.95
Total ash	3.09	4.27	4.62	4.93
L-methionine	0.31	0.38	0.38	0.38
L-lysine	0.92	0.91	0.92	0.93

To provide the following per kg of diet: Vit. A – 10 000 IU; vit. D3 – 1 500 IU; vit. E – 5 IU; vit. K – 2 mg; riboflavin – 3 mg; pantothenic acid – 10 mg; nicotine acid – 25 mg; chlorine – 350 mg; folic acid – 1 mg, magnesium – 56 mg; iodine – 1 mg; iron – 20 mg; zinc – 50 mg; cobalt – 1.25 mg

and housed in cages of 1 metre square size. Each experimental unit was assigned to an experimental diet and fed the experimental diet *ad libitum* for 42 days. Feed intake was determined by subtracting the weight of the left over feed from the weight of the feed offered on the previous day. The rabbits were weighed at the beginning of the experiment and weekly thereafter.

Dressing percentage

At the end of the growth trial, 3 rabbits were randomly selected from each experimental group and one rabbit per replication making a total of 12 rabbits. The rabbits were slaughtered after taking the percentage live weight of the rabbits fed the different levels of palmitic acid fortified maize wet milling by-product. The weight of the carcass was taken including the viscera. The results are shown in Table 4 below.

Data analysis

The acquired data were subjected to one-way analysis of variance (ANOVA) as outlined by Snedecor and Cochran (1978). Where the ANOVA indicated significance for treatment effects, means were separated using Least Significant Difference (LSD) as also outlined by Snedecor and Cochran (1978).

RESULTS AND DISCUSSION

Chemical composition of palmitic acid fortified maize wet milling by-product

The proximate composition of the maize by-product is presented in Table 2. Crude fibre and NFE were reasonably better than the values of legume leaf meals such as *Cajanus cajan* (Udedibie and Igwe, 1987), *Sesbania sesban* (Brown *et al.*, 1987) and *Centrosema pubescens* and *Tridax procumbeus* (Udedibie *et al.*, 2001).

Table 2. Proximate composition of dried maize wet milling by-product fortified with palmitic acid

Nutrients	Composition (%)
Moisture	5.95
Crude protein	9.26
Crude fibre	6.50
Ether extract	28.88
Ash	0.60
NFE	48.81

The crude protein value was comparable to that of the whole maize grain, the fat/oil value was also high reflecting the fortification of the by-product with palmitic acid.

The performance of the animals on the 30% palmitic acid fortified maize wet milling by-product maintained a superior performance followed by

Table 3. Effect of palmitic acid fortified wet-milling by-product on the performance of weaner rabbits

Control diet based on milling by-product		Fortified maize wet			
Parameters	%	25%	30%	50%	±S
Number of animals	12	12	12	12	–
Average initial weight (g)	466	468	470	469	1.02
Average final weight (g)	1 462^{b}	1 479^{a}	1 482^{a}	1 470^{b}	0.28
Growth rate (g/d)	21.84^{a}	22.06^{a}	21.54^{b}	21.03^{b}	1.12
Feed intake (g/d)	65.12^{a}	68.81^{a}	63.84^{b}	61.08^{b}	2.00
Feed/gain ratio	2.98^{a}	3.12^{a}	2.96^{a}	2.90^{b}	0.43
Feed cost ($/kg)	$1.62	$.94	$.81	$.72	–
$/kg rabbit	$2	$1.88	$1.80	$1.60	–
Mortality	–	–	–	–	–

$^{a, b}$within row with different superscripts are significantly different ($P < 0.05$)

Table 4. Carcass yield (% live weight) of rabbits fed different levels of palmitic acid fortified maize wet milling by-product

	Inclusion levels of fortified by-product				
	0%	25%	30%	50%	SEM
Weight of animals (g)	1 200	1 290	1 311	1 205	0.94
Dressing %	73.01[b]	76.2[a]	75.4	72.6[b]	0.05
Viscera weight (g)	30.05[b]	34.6[a]	31.17[b]	36.3[a]	0.85
Lumbar region (g)	12.09b	12.37[a]	12.32[a]	11.04[b]	0.10
Head	9.09[b]	10.00[a]	8.78[b]	10.01[a]	0.77
Hind limbs	12.10[b]	14.83[a]	16.36[a]	12.02[b]	0.65
Fore limbs	9.08b	11.24[a]	12.00[a]	9.01[b]	0.11
Breast	4.26[b]	4.00b	4.55[a]	4.12[b]	0.22
Liver	3.28[a]	3.1[a]	3.01[a]	2.79[b]	0.03
Kidneys	0.80	0.75	0.73	0.70	0.02
Heart	1.05	0.98	0.92	0.88	0.04

[a, b]means on the same row not followed by the same letter are significantly different ($P < 0.05$)

25%. So there was no significant difference in the average final weight gain of the rabbits ($P > 0.05$) fed 30% and 25% of the by-product. However, significant differences were observed in those on 50% and 0% by-product.

The growth rate of rabbits on the 25% diet was higher followed by the 0% and 30% diets. Nevertheless, those on 50% showed a depressed growth rate, which can be due to the unpalatability of the by-product at the 50% level added.

The animals showed a higher feed intake at the 25% level and 0% level ($P > 0.05$) and the feed intake decreased for the 30% level to 50% level of inclusion.

Generally, the growth performance of rabbits was comparable to the average performance of domestic rabbits under ideal management conditions in the tropics (Rastogi, 1984; Aduku *et al.*, 1986; Udedibie *et al.*, 2001). Perhaps a much better performance would have been obtained if the feeds had been pelleted since pelleted diets were reported to be superior to diets in meal or ground forms (Harris *et al.*, 1983; Lebas, 1983). The performance of rabbits in this trial was in contrast to the very poor performance of rabbits fed diets containing leaf meals from *Leucenea lencocephala* (Tangendjaja *et al.*, 1990; Onwudike, 1995) and *Robinia psuedoacacia* (Raharjo *et al.*, 1990) even at much lower replacement levels.

Dressing percentage, lumbar region weight and breast weight were lower ($P < 0.05$) for the 50% inclusion of the palmitic acid fortified maize wet-milling by-product while the inclusion of the by-product increased ($P > 0.05$) the viscera weight. No mortality was recorded throughout the experiment.

At the time of the experiment, the costs of the various feed ingredients used to formulate the control diet were \$1 (one dollar) per kilogram of control diet; consequently the feed cost of producing a kilogram of rabbit in the group was \$2 (two dollars). Assuming that the rabbit producer obtained the maize wet-milling by-product at zero cost, he would invariably make savings of up to 50% of the feed cost.

CONCLUSIONS

The data acquired in this experiment have indicated a strong promise for the palmitic acid fortified maize wet milling by-product as a good source of feedstuff for the rabbit industry in Nigeria and any other area where it could be available. They are

therefore highly recommended for full exploitation in that regard.

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Received: 03–04–16
Accepted after corrections: 03–09–23

ABSTRAKT

Vliv zkrmování vedlejšího produktu z mletí kukuřice za mokra obohaceného kyselinou palmitovou na užitkovost odstavených králíků

Byl proveden pokus trvající šest týdnů, který byl zaměřený na stanovení vlivu vedlejšího produktu z mletí kukuřice za mokra obohaceného kyselinou palmitovou na užitkovost odstavených králíků. Čtyřicet osm odstavených králíků (plemene novozélandské bílé a holandské) bylo krmeno čtyřmi typy krmných dávek s 0%, 25%, 30% a 50% hladinou vedlejšího produktu z mletí kukuřice za mokra obohaceného kyselinou palmitovou. Tyto čtyři varianty byly opakovány třikrát se čtyřmi odstavenými králíky na opakování. Kukuřičný vedlejší produkt jsme nejprve sušili na obsah vlhkosti 8 %; dále jsme přidali 2 litry surové kyseliny palmitové koupené v obchodě ke 100 kg kukuřičného vedlejšího produktu a opět jsme ho sušili na obsah vlhkosti 6 % a poté použili do pokusné krmné dávky tak, že kontrola (0 %) neobsahovala žádný vedlejší produkt z mletí kukuřice za mokra, 25% krmná dávka obsahovala 25 %

vedlejšího produktu nahrazujícího kukuřici, 30% a 50% krmné dávky obsahovaly 30 % resp. 50 % náhrady kukuřice. Každou z experimentálních krmných dávek jsme začali náhodně zkrmovat čtyřem skupinám po 12 odstavených králících po dobu šesti týdnů (42 dní). Sledovali jsme příjem krmiva, rychlost růstu a koeficient konverze krmiva. Analýza těchto hodnot nepřinesla žádné významné rozdíly ($P < 0,05$) v rychlosti růstu, příjmu krmiva a koeficientu konverze krmiva mezi kontrolou s 0 % vedlejšího produktu z mletí kukuřice za mokra obohaceného kyselinou palmitovou a variantami s 25 %, 30 % a 50 % tohoto produktu. Optimální užitkovost králíků dostávajících 30 % a 25 % vedlejšího produktu byla však vyšší ($P < 0,05$) než u ostatních pokusných variant. Výsledky jatečné výtěžnosti nenaznačily žádné významné rozdíly ($P < 0,05$) v hmotnosti beder a v hmotnosti přední části jatečně upraveného těla, ale poukázaly na rozdíly v hmotnosti vnitřních orgánů u variant s 30 % a 25 % vedlejšího produktu. Použití této náhražky značně snížilo výrobní náklady.

Klíčová slova: kyselina palmitová; vedlejší produkt z mletí kukuřice za mokra; odstavení králíci

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Influence of slaughterhouse handling on the quality of beef carcasses

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ABSTRACT: Along with the search for new methods of beef carcass classification using bioelectrical impedance (BIA) (Bohuslávek *et al.*, 2002) some quality characteristics that could influence the results of BIA measurement or bear on them (pH value, texture, colour) were examined. The influence of carcass hanging and pre-slaughter housing on quality characteristics was studied in selected meat cuts: round, loin and shoulder. The pH value was measured at the end of slaughter line 45 min *p. m.* (pH_0) and after cooling (pH_{24}, pH_{48}). The measured shear force (Warner-Bratzler shear test) and colour (reflectance spectrophotometry) were related to pH values. As expected, the colour (lightness) was indirectly dependent on pH_{24} ($L^* = 113.68 \exp[0.2163.pH_{24}]$. The housing system and sex of cattle influenced the pH development and texture significantly. The most important fact is that the differences in pH values (average of 250 carcasses) between the left ($pH_0 = 6.63$) and right ($pH_0 = 6.67$) side of beef (MLLT) were not statistically significant similarly like the differences in the texture of muscles in both half-carcasses. Thus the hanging mode does not have a significant influence on pH value 45 min *p. m.*, i.e. if the carcass is evaluated by measurement of bioelectrical impedance.

Keywords: beef carcass; pH; colour; texture; pre-slaughter housing; hanging

Different systems are suggested for carcass classification; the system SEUROP is generally used in the European region. Besides subjective evaluation, different objective methods are proposed or currently used: estimation of carcass conformation, muscle formation and fat ratio; use of video image analysis, sonography and measurement of electrical properties. One of these methods is bioelectrical impedance analysis (BIA) (Bohuslávek, 2002).

Some carcass characteristics can influence not only the beef quality including sensory properties (colour, texture, taste) but also the electrical properties and interfere with the measurement of bioelectrical impedance in this way. The early *post mortem* pH decrease as a result of anaerobic transformation of glycogen to lactic acid is one of these properties. It is influenced by several factors such as genetic constitution of the animal, different intravital factors and handling of animals immediately before slaughter. The slaughter technology (the technique of stunning and exsanguination, cooling, etc.) can also contribute to these factors (Steinhauser *et al.*, 2000).

The pH value decrease is not only obvious and very simply measurable but also it can characterise the post-mortal biochemical changes. Besides, there is a close correlation of pH value with colour, water-holding capacity (WHC) and meat texture. If the pH value approximates to the isoelectrical point, WHC reaches a minimum and the colour (lightness) increases (Hamm, 1972).

The grounds for myopathies are commonly known – it is mostly the inappropriate handling of animals, uptake of the glycolytic potential and thus insufficient acidification of meat *post mortem*. The DFD meat appears if the glycogen concentration (more exactly glycolytic potential) in the muscle is low at the moment of death. In addition to other influences the depletion of glycogen reserves can

Supported by the Grant Agency of the Czech Republic (Project No. 102/01/1344).

occur during waiting in a slaughterhouse (sex activity, social hierarchy reconstruction) (Ingr, 1996).

The animal housing before slaughter is mostly designed for reassurance and relaxation after transport. The time of 2–4 hours is considered as ideal for cattle (Steinhauser *et al.*, 2000). The absence of this period, or on the contrary, a long stay of animals before slaughter can cause myopathies. The incidence of DFD myopathy (also in the case of a longer stay) can be reduced by the individual housing of bulls. The overnight housing of bulls in the slaughterhouse in individual boxes before slaughter reduces the incidence of DFD defect, and improves meat quality (pH_{24} and reflectance) contrary to housing in group pens (Franc *et al.*, 1990a,b).

A too long interval between stunning and exsanguination can accelerate metabolism and lactic acid can be avoided with blood – meat acidification is insufficient in such a case (Rösener *et al.*, 1989). Hanging before exsanguination can accelerate the uptake of glycogen. Large differences were observed in pigs between the side of pork on which the carcass hangs and the other side that was free (Pipek – unpublished results).

The high ultimate pH value as a result of muscle glycogen depletion before slaughter influences the meat quality (particularly meat texture) significantly. It means that different pre-slaughter factors influencing the development of pH value can affect meat texture. DFD meat is associated with a higher grade of tenderisation or higher resulting tenderness. DFD meat is often distinguished using the measurement of pH value 24 hours *post mortem*; the meat whose pH24 is higher than 6.2 is usually considered as DFD meat (Honikel, 2000).

However, the relationship between the ultimate pH and tenderness is controversial. Some authors found a linear dependence of these parameters whereas others observed a curvilinear dependence with minimal tenderness (maximum shear force) in the range of pH_{24} from 5.8 to 6.3. They suggest different proteolytic activity responsible for meat toughness at pH value from 5.8 to 6.3. In meat with pH value higher than 6.3 the activity of neutral proteases calpains is favoured and at low pH (<5.8) enhanced cathepsin activity occurs. At intermediate pH values the pH is neither optimal for calpains nor for cathepsin activity resulting in the lowest degree of meat tenderisation during ageing (Silva, 1999; Pearson and Dutson, 1999; Wulf *et al.*, 2002).

Bull carcasses usually have higher ultimate pH values than cow and heifer carcasses. Because of the higher intramuscular fat content and lower thickness of muscle fibres the meat of cows is more tender than that of bulls, but it is necessary to take into account their age. Toughness of bull meat relates to its major inclination to DFD meat in comparison with meat of cows (D'Souza, 2002). The latter statement is however controversial to statements of other authors (see above).

The primary goal of this investigation was to evaluate the importance of some factors having a possible influence on the measurement of bioelectrical impedance. At the same time, the importance of some factors influencing beef quality was proved under industrial conditions.

MATERIAL AND METHODS

Material

The properties of beef carcasses (n = 250) were investigated on a modern industrial slaughter line under usual technological processing. The animals were housed during the night – nearly 10–12 hours. The animals belonged to the Czech Pied breed or they were hybrids with a prevailing ratio of this breed. Nearly 60 animals in each group were taken into consideration with the exception of heifers. There were only 8 heifers available, thus these data are given only as preliminary ones.

The animals were slaughtered by ordinary technology with a stunning gun (Schermer gun); the carcass was hung on one hind leg and then exsanguinated during 1 minute. Cooling (3 hours in an air stream –1°C) and cool storage at 3°C followed the slaughter processing. All measurements of pH value were carried out on the carcasses. The influence of the mode of carcass hanging during exsanguination was investigated; in addition, the effect of sex, pre-slaughter housing (together or individually) was also studied. The samples for laboratory investigations were taken from different parts of loin (*musculus longissimus lumborum et thoracis*) at the 10th rib, round (*musculus semimembranosus*) and shoulder (*musculus triceps brachii*) after the last measurement of pH value, i.e. 48 h *post mortem*.

The meat samples were placed in a cooling box and after transport to the laboratory stored at the temperature of 4°C.

Methods

pH-value was measured in the corresponding part of the whole carcasses at the end of slaughter line (pH_0), and after 24 and 48 h of storage under 3°C. Puncture pH-meter CMH 3530 (Greisinger Electronic GmbH) with combined glass/calomel electrode was used for measurements.

Texture of meat was measured 72 h *post mortem* by the shear method on Instron 5544 equipped with Warner-Bratzler shear device. Before analysis the samples of meat were cut into strips 60 mm long in the direction of muscle fibres, of rectangular cross-section 20 × 15 mm. The shear blade was applied perpendicularly to the fibre direction at 80 mm per minute. The course of shear force was measured and recorded according to the time of measurement until the complete cut of sample. Measured data were evaluated using software Series IX. The force needed to shear a meat sample characterised meat tenderness.

Colour was measured with spectrophotometer Minolta CM-2600d that directly transmits the measured values of reflectance (reflectance spectra) to the variables of CIE system: lightness L* and coordinates a* and b*.

Statistical analysis of measured data was performed using Microsoft Excel, version 2000, and/or Stat Soft. The *t*-test was carried out at a significance level $P < 0.05$.

RESULTS AND DISCUSSION

The importance of some factors that could influence the measurement of bioelectrical impedance (see above) or bear on it was evaluated. These factors include pH development, texture and colour of meat. The most important and readily measurable characteristic of meat is the pH value development and it is commonly used as a decisive criterion for quality evaluation. The characteristics such as colour and texture depend on pH value directly.

The mode of hanging immediately after exsanguination can cause a different pH decrease in the left contrary to the right side of beef. The hanging of the carcass on one leg immediately after slaughter can lead to important depletion of glycogen and therefore abnormal conversion to lactic acid and different pH value. It was found in our previous observations where we described experiments with pigs that the pH_0 value in the leg on which the carcass was hung was significantly different from the other free one. The mode of carcass hanging after stunning (via the Achilles tendon and pelvic suspension) in pigs was also studied by Fischer *et al.* (2000), who found that the pelvic suspension reduced weight losses.

However, no significant differences at a significance level $P < 0.05$ were found in pH_0 values between the left and the right sides of beef (Table 1 and Figure 1). Neither is evident the difference according to pH values after 24 and 48 hours. Unfortunately, this cannot be compared with similar measurement of other authors. The only data we found in the literature concern sheep. No differences in ultimate pH were found between the left and right side of lamb in *musculus longissimus* by Geesink *et al.* (2001). pH of the *musculus longissimus lumborum et thoracis* was measured in both the left and right side in 0.5, 1.5, 4 and 24 h *p. m.* in all carcasses by McGeehin *et al.* (2001). The *post*

Table 1. Changes in the pH value of *musculus longissimus lumborum et thoracis* in the left and right side of beef for individual groups of cattle (60 animals in each group; only 8 heifers)

	Time *p. m.*	Side of beef	Bulls individually	Bulls in group	Cows individually	Cows in group	Heifers	Total
pH_0	45 min	left	6.59 ± 0.19	6.81 ± 0.21	6.73 ± 0.20	6.72 ± 0.12	6.86 ± 0.15	6.63 ± 0.21
		right	6.58 ± 0.19	6.89 ± 0.19	6.78 ± 0.18	6.75 ± 0.17	6.9 ± 0.14	
pH_{24}	24 h	left	6.01 ± 0.20	6.29 ± 0.20	6.05 ± 0.10	6.15 ± 0.17	6.02 ± 0.16	6.67 ± 0.22
		right	6.01 ± 0.17	6.32 ± 0.19	6.06 ± 0.12	6.19 ± 0.15	6.08 ± 0,15	
pH_{48}	48 h	left	5.92 ± 0.14	6.10 ± 0.18	*	5.92 ± 0.19	*	6.14 ± 0.20
		right	5.93 ± 0.17	6.08 ± 0.20	*	5.99 ± 0.16	*	6.14 ± 0.19

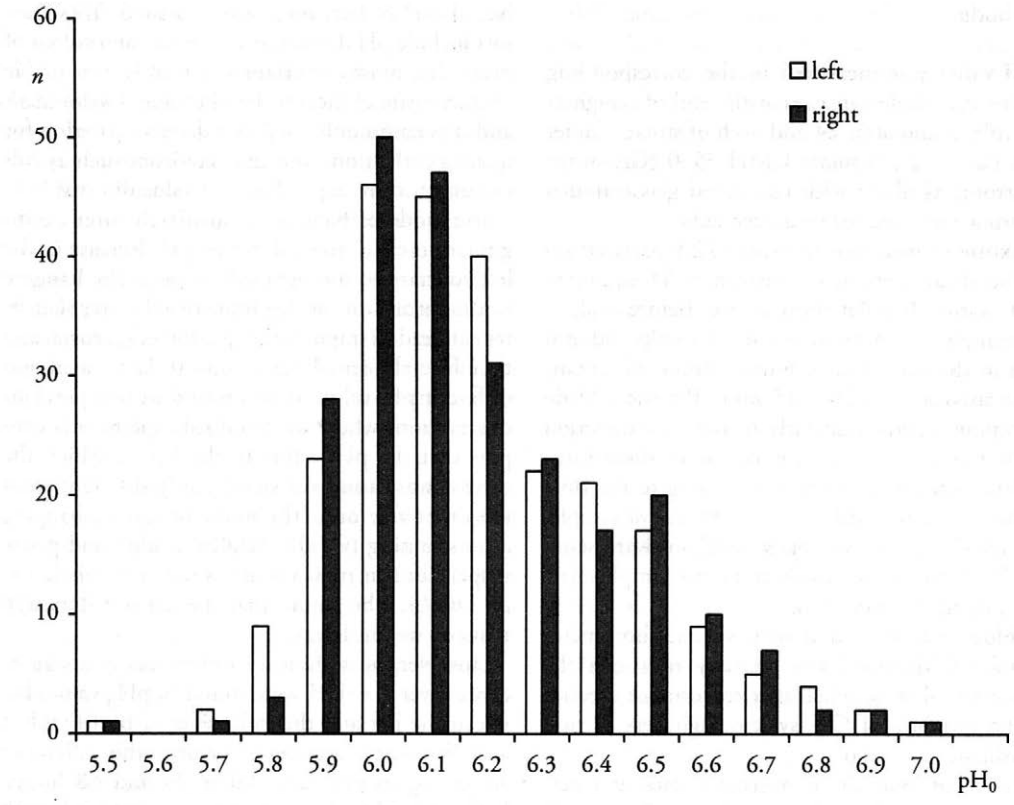

Figure 1. Frequency (n) of different pH_0 values in *musculus longissimus lumborum et thoracis* – comparison of the left and right sides of beef (together 250 animals)

mortem decrease in pH showed an inherently variable nature, independent of many of the parameters measured.

In our experiments there were no differences in pH between the left and right half-carcasses either (see Tables 1–3). A possible explanation can consist in different dynamics of *post mortem* glycolysis between cattle and pigs. Regardless of the reason for this statistically insignificant difference it is important that the measurement of bioelectrical impedance cannot be influenced by the difference in pH values between both half-carcasses.

So the most important conclusion is that the hanging mode cannot influence the results of bioimpedance measurement through different pH values, and thus it does not matter which half-carcass will be used for measurement. The final value will not be influenced if the carcass is occasionally hung on the other leg at the beginning of slaughter line.

Significant differences in pH value were found between individual animal groups. It is apparent that group housing of bulls before slaughter implies higher pH values compared to individual housing. This concerns pH_0 values at the end of slaughter line (at the place of classification) and it is also evident in pH measurement 24 or 48 hours *post mortem*. This observation confirms the earlier published data (e.g. Franc *et al.*, 1990a – see above).

Although the detection of myopathies was not the goal of this paper, some values indicated DFD myopathy (Honikel, 2000). The higher pH value resulted in the change of lightness and shear force values – see below.

The pre-slaughter housing of cows is not mostly considered to be important with regard to their temperament. The cows are not usually affected by the pre-slaughter collective housing and by the reconstruction of social structures (Franc *et al.*, 1990b). No significant differences between the cows that were housed individually or in groups before slaughter were observed in our experiments. (The results for heifers are preliminary without sta-

tistical evaluation with respect to the small number of carcasses.)

It is also interesting that both groups of cows (housed together or individually before slaughter) have the higher pH_0 value (45 min *p. m.*) than bulls from individual housing. However, during cool storage the pH values of these two animal groups become similar (Table 1). Nevertheless, this observation was only preliminary; it does not evaluate individual intravital factors in detail.

We assume that the pH value decreases (already during slaughter processing) more quickly in the individually housed bulls whereas this decrease concerning meat of cows was slow. Though they have enough of the glycolytic potential necessary for a sufficient decrease in pH value. As for the group-housed bulls, this decrease is not possible considering the depletion of glycolytic potential before slaughter. Similar results were obtained in a repeated experiment (Table 2).

DFD myopathy is usually detected by measuring the pH value 24 hours *post mortem*. Although the pH value 45 min *p. m.* is essential for BIA measurement, we also measured the pH_{24} value. The pH value at the end of slaughter line (pH_0) where the BIA measurements are carried out is independent of the total glycolytic potential and the content of produced lactic acid and ultimate pH value, but it depends on the dynamics of its decrease. It is also important that the pH value decreases in both half-carcasses at the same rate. Even though we compared the left and the right half-carcass in individual investigated groups of animals, in no case were any differences in pH values (and other measured variables) found.

This statement is the most important as the main intention of this study was not to follow the progress of ageing but to find the differences in pH value immediately at the end of slaughter line and its possible influence on electrical properties. It appears that there are some differences between carcasses and it will be necessary to find the association between pH and impedance during methodology verification.

It is obvious that there were differences in the dynamics of *post mortem* glycolysis in different animals and meat cuts. The loading of muscles and physiological disposition certainly act jointly with other factors.

Differences in pH values of selected meat cuts – round (*m. semimembranosus*), loin (*m. longissimus lumborum et thoracis*) and shoulder (*m. triceps brachii*) were observed (Table 3). But the differences between the two sides were not significant. Small (but insignificant) differences were found in the round, where we can consider a higher depletion of glycolytic potential in the left round from the carcass that was hung at the moment before exsanguination. This cut could indicate a possible influence of physical effort as a consequence of the action of the whole weight of hung carcass, but as previously mentioned this difference was not significant.

At the same time, the properties that do not have a direct influence on the results of BIA classification

Table 2. Changes in pH of *musculus longissimus lumborum et thoracis post mortem* in several groups of cattle (repeated experiment; 60 animals in each group)

pH	Side of beef	Bulls individually	Bulls in group	Cows in group
45 min	left	6.36 ± 0.17	6.61 ± 0.21	6.67 ± 0.16
	right	6.37 ± 0.19	6.62 ± 0.19	6.63 ± 0.19
24 h	left	5.97 ± 0.17	6.19 ± 0.21	5.98 ± 0.21

Table 3. pH values in different meat cuts (60 bulls)

pH	Side of beef	Shoulder	Round	Loin
45 min	left	6.58 ± 0.18	6.44 ± 0.19	6.46 ± 0.16
	right	6.57 ± 0.17	6.40 ± 0.16	6.48 ± 0.20
24 h	left	5.79 ± 0.18	6.08 ± 0.20	6.19 ± 0.21

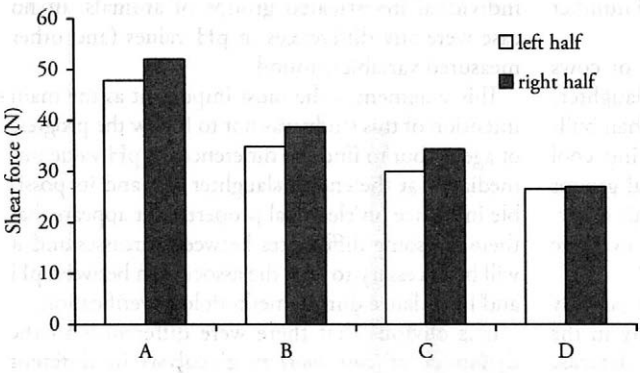

Figure 2. Texture (as shear force in N) of *musculus longissimus lumborum et thoracis*

A – bulls in group, B – bulls individually, C – cows in group, D – heifers

but are related to the development of *post mortem* glycolysis were evaluated.

No differences in texture were found between the right and left side of beef. Thus the mode of hanging did not influence the meat texture. On the other hand, the texture of meat was influenced by the sex of cattle. The meat of heifers and cows was more tender than that of bulls, probably due to higher fat content in the meat of females.

The housing mode before slaughter also influenced the meat texture. Meat of individually housed bulls was more tender (the measured shear force values was lower) than meat of bulls housed in the groups (Table 4, Figure 2).

The equations for linear regression describe the dependence of shear force (F) of bulls on pH value (pH_0, pH_{24}, pH_{48}): $n = 60$; $F = 13.453pH_0 - 43.451$, $r = 0.90$; $F = 11.661pH_{24} - 28.983$, $r = 0.71$; $F = 15{,}66pH_{48} - 45.73$, $r = 0.56$.

Table 4. Lightness of meat (*musculus longissimus lumborum et thoracis*) as influenced by the pH value 24 h *post mortem* (35 animals)

Left		Right		Left		Right	
pH_{24}	L*	pH_{24}	L*	pH_{24}	L*	pH_{24}	L*
5.88	31.56	5.92	33.19	5.92	30.56	6.11	30.55
7.05	23.32	6.96	27.39	5.92	30.98	6.14	28.47
6.00	31.40	6.00	28.41	6.07	32.50	6.18	31.87
6.93	23.57	6.89	26.88	5.92	31.02	5.81	33.33
6.93	24.35	6.97	25.06	5.77	34.37	6.26	32.18
7.05	24.97	6.94	22.53	5.83	29.56	5.83	28.68
6.06	28.28	6.20	28.33	6.45	25.40	6.41	28.47
6.48	26.86	6.49	25.46	5.84	29.25	5.99	30.67
5.88	33.62	5.89	32.99	5.92	30.75	5.89	30.71
6.01	31.06	5.98	32.77	5.88	30.01	6.01	31.14
5.96	33.74	6.02	33.90	6.29	29.51	6.11	30.17
5.91	35.38	5.93	33.75	5.96	28.07	5.98	27.21
5.94	30.97	5.96	32.10	5.91	31.48	5.93	31.53
5.92	31.16	5.92	31.82	6.40	31.37	6.37	31.42
6.16	33.73	6.19	32.61	5.92	30.56	6.11	30.55
5.91	29.04	5.87	30.08	5.92	30.98	6.14	28.47
6.08	31.44	5.98	32.82	6.07	32.50	6.18	31.87
6.40	31.37	6.37	31.42				

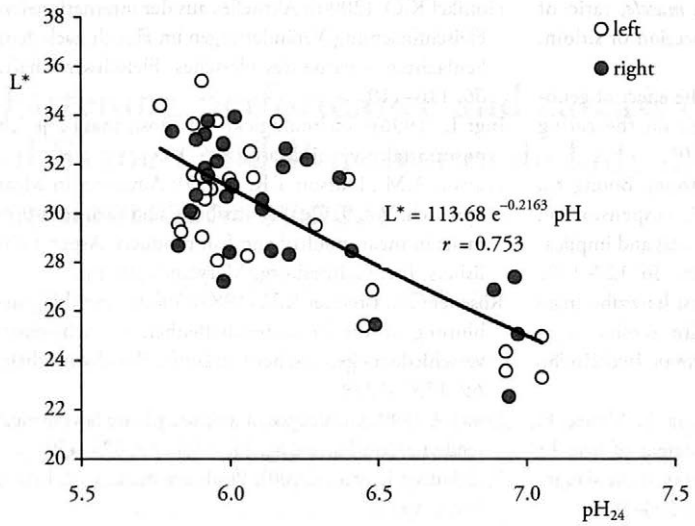

Figure 3. Lightness of meat (*musculus longissimus lumborum et thoracis*) as influenced by the pH value 24 h *post mortem* (35 animals)

Table 5. The values of shear force (N) measured for *musculus longissimus lumborum et thoracis* in different groups of cattle

	Side of beef	Bulls individually	Bulls in group	Cows in group	Heifers
Shear force (N)	left	34.8 ± 4.7	47.8 ± 10.7	29.9 ± 2.1	26.4 ± 1.0
	right	38.7 ± 2.8	52.0 ± 11.1	34.3 ± 3.2	26.9 ± 0.1

A more detailed study of tenderness as influenced by intravital and technological factors will be described in the next paper.

Likewise the colour of meat that represents the most apparent characteristic was influenced by pH values. In Figure 3 (or in Table 5) the increase in lightness L* with increased pH value L* = 113.68 exp [0.2163.pH_{24}]) is evident. It confirms the common knowledge that meat from individually housed bulls with high pH value has a disposition to DFD myopathy and it requires separating the bulls during pre-slaughter housing. Further study deals with intravital factors in detail, but it was not an object of observations. It is essential that there were no obvious differences in colour between the left and right side of beef.

CONCLUSIONS

The influence of carcass hanging, pre-slaughter housing and sex of cattle on pH decrease in meat was investigated under industrial conditions. The pH value was not significantly influenced by these factors with one exception – the meat of bulls that were hold together (in group) before slaughter had the higher pH values. Further more detailed investigation of intravital factors will be an object of a separate study. Colour (lightness) and tenderness were influenced by the ultimate pH value.

No differences were found between pH values in the left and right side of beef. It is very important for measurements of bioelectrical impedance that thus cannot be influenced by different pH_0 (45 min *p. m.*) as it was proved that the mode of hanging does not influence this pH_0 value.

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Received: 02–11–23
Accepted after corrections: 03–09–23

ABSTRAKT

Vliv zacházení se zvířaty na jatkách na kvalitu hovězích JUT

Současně s hledáním nových metod pro klasifikaci hovězích jatečně upravených těl (JUT) pomocí bioelektrické impedance (BIA) (Bohuslávek *et al.*, 2002a) byly vyhodnoceny i některé parametry (pH, textura, barva), které mohou ovlivnit výsledky měření. V ušlechtilých částech svaloviny (kýta, roštěnec, plec) byl sledován vliv způsobu zavěšení jatečných těl, pohlaví i předporážkového ustájení na tyto veličiny. Byly měřeny hodnoty pH na konci jateční linky 45 min *p. m.* (pH_0) a po vychlazení (pH_{24}, pH_{48}) a dále síla ve střihu (Warner-Bratzler) a barva (spektrofotometr Minolta). Naměřené hodnoty barvy a textury byly dány do souvislosti s pH. Barva (světlost) podle očekávání závisela nepřímo na pH_{24} ($L^* = 113{,}68 \exp[0{,}2163.pH_{24}]$). Pozornost byla zaměřena především na srovnání průběhu pH u obou jatečních půlek (rozdíl v zavěšení). Rozdíly mezi hodnotami pH (průměr 250 JUT) ve svalovině (MLLT) v levé ($pH_0 = 6{,}63$) a pravé ($pH_0 = 6{,}67$) půlce nebyly statisticky významné, stejně jako rozdíly textury mezi svaly obou jatečných půlek. I když způsob ustájení a pohlaví ovlivnily změny pH, neměly významný vliv na rozdíly mezi oběma půlkami. Způsob zavěšení tedy nemá významný vliv na pH 45 min *p. m.*, kdy se vyhodnocuje složení JUT pomocí bioimpedance.

Klíčová slova: jatečně upravené tělo skotu; pH; barva; textura; předporážkové ustájení; zavěšení

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Fattening performance and carcass characteristics of Saanen and Bornova male kids under an intensive management system

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ABSTRACT: Twenty kids of Saanen (n = 10) and Bornova (n = 10) breed were individually fattened for 56 days under an intensive management system. Fattening performance, slaughter traits and carcass characteristics were evaluated. Saanen kids had significantly higher average daily gain (161.52 g versus 132.05 g) and daily concentrate intake (851 g versus 725 g) compared to Bornova kids ($P < 0.05$). Warm carcass yield was found significantly higher ($P < 0.05$) in Bornova kids compared to Saanen kids (55.19% versus 52.20%). The two breeds differed in some non-carcass parts significantly ($P < 0.05$). There were no significant differences in body organs and carcass measurements except for leg length and width ($P < 0.05$). In general, prime cuts did not differ in these breeds significantly but the MLD area was significantly higher in Bornova kids ($P < 0.05$). Saanen kids had meat of pale and pink colour, which is the most acceptable to consumers.

Keywords: kids; fattening performance; carcass characteristics; meat quality

Goats take an important place in the economics of animal production of Turkey and in the nutrition of its population. The number of goats in Turkey is about 7.2 million. According to the statistical yearbook of Turkey in 2001 (SIS, 2001), out of 492 thousand tons of total meat produced in Turkey in 2000, 22 thousand tons came from ordinary goats and kids including Angora. The most important income of Turkish goat breeders is provided by milk production and sale of kids, they are marketed seasonally during the springtime in Turkey (Şengonca *et al.*, 2000). In developing countries, kids are usually reared naturally under extensive conditions and this permits the production of kids for human consumption at the live weight of ca. 10 kg (Yalçın, 1986; Anous and Mourad, 1993). It is well known that young animals fed high concentrate diets generally have higher daily gains, dressing percentage and carcass quality than those produced in a forage system. Genetic differences between breeds and types of goats in terms of growth and production potential are obvious as reported by various authors (Warmington and Kirton, 1990). Differences in carcass characteristics suggest that existing breeds are used for different production and marketing environments by establishing suitable mating systems and breed combinations (Ruvuna *et al.*, 1992). Shahjalal *et al.* (1992) found that high-energy diets increased carcass weight, dressing percentage and the area of *m. longissimus dorsi* in British Angora goats. Johson and McGowan (1998) also reported that kids from an intensive system had higher slaughter and carcass weight, higher dressing percentage and larger *longissimus dorsi* areas than goats raised under a semi-intensive system. Little information was published about the utilization of genetic potential of different goat breeds for maximizing meat production (Anous and Mourad, 1993) and colour parameters for goat meat from male animals (Dhanda *et al.*, 1999b; Todaro *et al.*, 2002). Until now, fattening performance and carcass characteristics for Saanen and Bornova kids raised under an intensive system in western Turkey have not been documented well. Therefore, the present study was conducted

to evaluate male kids from Saanen and Bornova goats for fattening performance and carcass characteristics under an intensive management system in the western part of Turkey.

MATERIAL AND METHODS

This study included 20 Saanen and Bornova male kids in total obtained from an Experimental Station of the Agricultural Faculty of Ege University at Izmir, Turkey. Bornova is a local genotype obtained by Improved White German × Maltese × Anglo Nubian crossing (Şengonca *et al.*, 2000). The kids born in winter 2001 were weaned from their mothers after 60 days suckling period. Then the male kids were divided into two groups Saanen and Bornova of 10 animals each and housed individually and fed intensively for 56 days. The intensive system involved feeding the kids with concentrate and alfalfa hay for their daily nutritional requirements. Hay was provided restrictively (100 g/day) and contained 18.69% crude protein and 1 942 kcal/kg metabolizable energy (ME) in dry matter (DM). In addition to alfalfa hay, the kids received *ad libitum* commercially available concentrate containing 24.58% crude protein and 3 063 kcal ME/kg DM in the mash form. Water was freely available. Individual feed consumption was recorded daily and live weight gain was checked in two-week intervals. The chemical analysis of the concentrate and alfalfa hay was conducted according to the German system (Naumann and Bassler, 1993). The chemical composition of diets on dry matter basis is presented in Table 1. At the end of the fattening period, five kids from each group were transported to a commercial abattoir. Kids were held overnight without feed before slaughter. The next morning a standard commercial slaughter procedure was carried out. Live weights (after the overnight period without feed) and warm carcass weights (with kidney and pelvic fat removed) were collected. The pelt, head, feet, internal organs (lungs and trachea, liver, kidney) and empty stomach compartments (rumen, reticulum, omasum and abomasum) were weighed separately. Carcasses were chilled for 24 h at 2°C. In 24 h *post mortem*, the carcasses were reweighed. Each carcass was evaluated for conformation and fatness according to the EUROP carcass classification system for lambs (CEE No. 2137/92, No. 461/93). Carcass was classified for conformation (scale from E = excellent (1) to P = poor (5) and fatness (scale from 1 = entire carcass covered with fat to 5 = none or low fat cover) according to the visual scores in the EUROP system. The five classes for conformation (1–15) and five classes for fatness (1–15) were divided into three subclasses: + or – (De Boer *et al.*, 1974). Conformation and fatness were scored descending from 15 (high score) to 1 (low score). Carcass was split longitudinally on a band saw and the following carcass measurements were taken from the left side of carcass: carcass length, carcass depth, leg length, leg circumference, leg width, MLD length, body fat thickness. The carcass was also separated into five prime cuts: neck, shoulder, breast, loin + sirloin and leg (Figure 1). The cuts and three ribs (11–13th rib) were weighed. The MLD muscles were carefully dissected from the left side sampled and their area was measured on a transparent sheet with digital planimeter. These samples were transported to a lab in polyethylene bags. After the first cut of the surface, samples were placed in a styrofoam tray and the first measurements were taken. The styrofoam tray was overwrapped with oxygen-permeable film and stored for 5 days at 4°C. The colour was determined using Minolta CM 508d

Table 1. Chemical composition of concentrate and alfalfa hay (g/kg DM)

Nutrient	Concentrate	Alfalfa hay
Organic matter (OM)	923.7	887.5
Crude protein (CP)	245.8	186.9
Ether extract (EE)	47.8	13.7
Crude fibre (CF)	56.5	268.4
Nitrogen free extractives (NFE)	573.6	418.5
Total ash (TA)	76.3	112.5
Metabolizable energy (ME, kcal/kg)	3 063	1 942

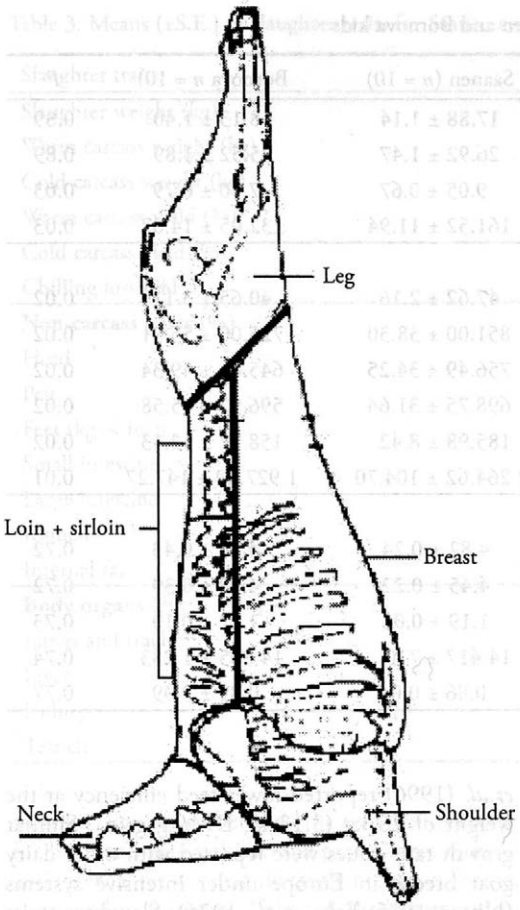

Figure 1. The five anatomical joints

spectrocolorimeter and CIE (1986) detecting lightness (L*), red colour coordinate (a*), yellow colour coordinate (yellowness) with D65 illumination, and (10^0) standard observer.

Data were analysed using the linear model (GLM) procedure of SAS (1985) mixed model least squares and maximum likelihood computer package. The following statistical model was used for the analyses of each measurement.

$$Y_{ij} = \mu + a_i + e_{ij}$$

where: Y_{ij} = individual observation
μ = general mean
a_i = effect of ith breed (i =1,2)
e_{ij} = residual error normally distributed with mean 0 and variance σ_e^2

The model was designed to determine the effect of breed on fattening performance and carcass traits. All traits were corrected by initial weight as a covariate. Least squares means were calculated for all variables in the study and the LSD test was used to determine significance of differences.

RESULTS AND DISCUSSION

Initial weight (IW) and final weight (FW) for Saanen and Bornova kids were 17.88 kg and 26.92 kg, and 18.13 kg and 25.52 kg, respectively (Table 2). There was no significant effect of breed on the initial and final weight of kids. The differences between the average weight gain (AWG) and daily weight gains (ADWG) for 56 days were found significant ($P < 0.05$). The average daily weight gain was higher in Saanen kids with 161.52 g than in Bornova kids (132.05 g). Similar results were reported by Alçiçek *et al.* (1995), who found that daily weight gain was on average 141 g for Bornova and Saanen kids fed diets containing 20% crude protein and 2 700 kcal/kg ME. Negesse *et al.* (2001) also reported the daily gain of 181 g for male Saanen kids. In the present study, Saanen kids grew faster than Bornova kids. These results confirm the results of Demirören *et al.* (1999), who found higher growth rate in Saanen kids than in Bornova ones. However, daily weight gain of Saanen kids in this study was lower than the results reported by Negesse *et al.* (2001). On the other hand, our findings are in agreement with the results of McGregor (1985) and Dhanda *et al.* (1999a). In general as the fattening period extended, differences between the two breeds in total concentrate intake (TCI) of kids for 56 days were found significant ($P < 0.05$). The highest total concentrate intake was observed in Saanen kids with 47.62 kg and Bornova kids followed this group with 40.65 kg and increased linearly until 56 days. On the basis of different fattening periods, the effect of breed on total concentrate intake of kids was also found significant ($P < 0.05$). The daily concentrate intake (DCI) for Saanen and Bornova kids was 851 g and 725 g, respectively. The differences in daily concentrate intake for the whole fattening period of 56 days were also significant ($P < 0.05$). Daily dry matter intake (DMI), organic matter intake (OMI) and crude protein intake (CPI) from the concentrate for Saanen and Bornova kids were 756.49 g and 645.81 g, 698.75 g and 596.52 g, and 185.98 g

Table 2. Means (±S.E.) of fattening performance for Saanen and Bornova kids

Fattening performance	Saanen (n = 10)	Bornova n = 10)	P
Initial weight (IW, kg/hd)	17.88 ± 1.14	18.13 ± 1.40	0.89
Final weight (FW, kg/hd)	26.92 ± 1.47	25.52 ± 1.89	0.89
Average weight gain (AWG, kg/hd)	9.05 ± 0.67	7.40 ± 0.79	0.03
Average daily weight gain (ADWG, g/hd)	161.52 ± 11.94	132.05 ± 14.07	0.03
Feed intake			
Total concentrate intake (TCI, kg/hd)	47.62 ± 2.16	40.65 ± 3.11	0.02
Daily concentrate intake (DCI, g/hd)	851.00 ± 38.30	725.00 ± 55.91	0.02
Dry matter intake (DMI, g/d/hd)	756.49 ± 34.25	645.81 ± 49.34	0.02
Organic matter intake (OMI, g/d/hd)	698.75 ± 31.64	596.52 ± 45.58	0.02
Crude protein intake (CPI, g/d/hd)	185.98 ± 8.42	158.77 ± 12.13	0.02
Metabolizable energy intake (MEI, kcal/d/hd)	2 264.62 ± 104.70	1 927.29 ± 147.27	0.01
Feed efficiency			
DMI (kg/kg gain)	4.82 ± 0.24	4.96 ± 0.43	0.72
OMI (kg/kg gain)	4.45 ± 0.22	4.58 ± 0.39	0.72
CPI (kg/kg gain)	1.19 ± 0.06	1.22 ± 0.10	0.73
MEI (kcal/kg gain)	14 417 ± 710	14 805 ± 1 283	0.74
Protein efficiency ratio (PER, kg gain/kg CPI)	0.86 ± 0.04	0.89 ± 0.09	0.77

and 158.77 g, respectively. All of these parameters were found significantly ($P < 0.05$) higher in the kids of Saanen breed. It is also shown that there were differences in the metabolizable energy intake (MEI) from the concentrate between Saanen and Bornova kids ($P < 0.01$). These results were confirmed by Muhikambele *et al.* (1996), who found daily DM intake of 751 g and daily weight gain of 222 g in Saanen kids at slaughter weight of 26 kg. When the two breeds were compared from the aspect of feed efficiencies for the whole fattening period, no significant differences were observed (Table 2). Dry matter intake (DMI), organic matter intake (OMI), crude protein intake (CPI) and metabolizable energy intake (MEI) for per kg of live weight gain in Saanen and Bornova male kids were 4.82 and 4.96 kg, 4.45 and 4.58 kg, 1.19 and 1.22 kg, 14 417 kcal and 14 805 kcal, respectively. Live weight gain per kg of crude protein regarded as Protein Efficiency Ratio (PER) for Saanen and Bornova kids was 0.86 kg and 0.89 kg, respectively. Similar results of feed intake and feed efficiency were reported by Negesse *et al.* (2001), who found that the dry matter intake and feed efficiency in male Saanen kids were 608 g and 4.79 kg DM/kg weight gain, respectively, whereas Muhikambele *et al.* (1996) reported lower feed efficiency at the weight of 26 kg (3.13 kg DM/kg gain). Similar growth rate values were reported with other dairy goat breeds in Europe under intensive systems (Nitter, 1975; Fehr *et al.*, 1976). Slaughter traits for Saanen and Bornova kids are given in Table 3. There was no significant difference between the two breeds in slaughter weight. Though no significant differences were found in slaughter weight between the two groups, Bornova kids showed higher slaughter weight than Saanen kids. Warm and cold carcass weights for Saanen and Bornova were 15.46 and 16.26 kg, 15.07 and 15.84 kg, respectively. However, warm and cold carcass yield was found significantly higher in Bornova compared to Saanen ($P < 0.05$), but chilling losses were similar. Carcass weights were similar with the other breeds slaughtered at the same age (Dhanda *et al.*, 1999a). Breed influenced the muscle content. It was approximately 3% higher in Bornova kids compared to Saanen (55.19% versus 52.20% for warm carcass; 53.78% versus 50.88% for cold carcass; $P < 0.05$). Our values of carcass yield are in agreement with the findings of Devendra and Owen (1983), Sanz *et al.* (1987), Dhanda *et al.* (1999a), Perez *et al.* (2001). Differences in the percentage of non-carcass parts

Table 3. Means (±S.E.) of slaughter traits for Saanen and Bornova kids

Slaughter traits	Saanen (n = 5)	Bornova (n = 5)	P
Slaughter weight (kg)	29.60 ± 1.05	29.45 ± 0.28	0.89
Warm carcass weight (kg)	15.46 ± 0.70	16.26 ± 0.22	0.32
Cold carcass weight (kg)	15.07 ± 0.68	15.84 ± 0.20	0.32
Warm carcass yield (%)	52.20 ± 1.15	55.19 ± 0.45	0.05
Cold carcass yield (%)	50.88 ± 1.16	53.78 ± 0.39	0.05
Chilling loss (%)	2.52 ± 0.11	2.55 ± 0.18	0.90
Non-carcass parts (%)			
Head	14.50 ± 0.23	12.20 ± 0.49	0.05
Pelt	14.23 ± 0.76	12.82 ± 0.38	0.15
Feet (kg, 4 feet)	12.44 ± 0.42	11.84 ± 0.16	0.23
Small intestine	4.45 ± 0.23	3.95 ± 0.36	0.29
Large intestine	3.47 ± 0.46	2.64 ± 0.33	0.19
Rumen	7.45 ± 0.54	8.45 ± 1.74	0.60
Internal fat	4.54 ± 0.36	3.33 ± 0.33	0.05
Body organs (%)			
Lungs and trachea	4.29 ± 1.69	2.22 ± 0.24	0.27
Liver	8.53 ± 0.61	8.08 ± 0.16	0.50
Kidney	1.05 ± 0.12	1.01 ± 0.01	0.74
Testicle	1.46 ± 0.07	1.07 ± 0.11	0.02

were not significant between the two breeds except for head and internal fat. The percentages of head and internal fat were significantly higher in Saanen compared to Bornova. Although the differences in the percentage of body organs between the two breeds were not significant, the percentage of the testicle was higher for Saanen.

Carcass and meat quality parameters are presented in Tables 4 and 5. Based on the findings of this study (Table 4), meat from carcasses of these two breeds did not display characteristics different from those of other types of goat breeds (Dhanda *et al.*, 1999a; Oman *et al.*, 2000). Carcass length, carcass depth, carcass width, leg circumference, MLD length for breeds did not differ ($P > 0.05$). But leg length and leg width were found significantly higher in Saanen ($P < 0.05$). Carcasses obtained from Bornova kids had slightly higher carcass conformation scores than those of Saanen kids. However, fatness scores were higher in Saanen kids. That means Saanen kids had lower cover fat than Bornova kids. The percentages of prime cuts are also presented in Table 4. While shoulder percentage in Saanen kids was higher than in Bornova kids, breast percentage was higher in Bornova kids compared to Saanen ($P < 0.05$). Neck and hind leg did not differ in the two breeds. However, the percentages of third ribs and MLD area were significantly higher in Bornova compared to Saanen (2.65% vs. 2.19%; 14.63 cm^2 vs. 8.66 cm^2 for Saanen vs. Bornova, respectively). Wahid *et al.* (1985) and Dhanda *et al.* (1999c) reported that the breed type affected the weight of prime cuts in goats.

Although only small differences were found in meat colour characteristics (Table 5) between the breeds in this study, lightness (L*) of Saanen meat was more stable than that of Bornova during the storage time. Redness (a*) and yellowness (b*) also increased in these two breeds during storage. However, this increase in a* and b* value was higher in Bornova kids than in Saanen kids. Bornova kids showed the L* value higher than Saanen kids. Likewise Borghese *et al.* (1990) reported that meat obtained from Saanen kids was lighter in colour. However, Saanen kids showed the a* value higher than Bornova kids for the first 2 days. In general, b* values were lower in Saanen except 2 days of storage time. Our results are in agreement with the results of Babiker *et al.* (1990), Dhanda *et al.* (1999b) and Todaro *et al.* (2002), who found that the meat

Table 4. Means (±S.E.) of carcass measurements and weight of prime cuts in Saanen and Bornova kids

Carcass measurements	Saanen (n = 5)	Bornova (n = 5)	P
Carcass length (cm)	61.64 ± 0.87	60.61 ± 0.48	0.26
Carcass depth (cm)	14.92 ± 0.25	14.70 ± 0.12	0.29
Carcass width (cm)	23.83 ± 0.03	24.07 ± 0.42	0.73
Leg length (cm)	39.76 ± 0.52	37.48 ± 0.69	0.05
Leg circumference (cm)	38.43 ± 0.75	38.19 ± 0.58	0.85
Leg width (cm)	14.09 ± 0.55	11.68 ± 0.51	0.05
MLD length (cm)	18.89 ± 0.20	18.60 ± 0.35	0.55
Conformation (1–15)	11.50 ± 0.29	11.75 ± 0.25	0.54
Fatness (1–15)	11.25 ± 0.48	10.50 ± 0.29	0.23
Body fat thickness (cm)	0.36 ± 0.04	0.37 ± 0.04	0.90
Prime cuts (%)			
Neck	9.85 ± 0.64	9.36 ± 0.08	0.48
Shoulder	19.59 ± 0.20	18.31 ± 0.32	0.02
Loin + sirloin	24.34 ± 0.58	22.00 ± 0.98	0.09
Breast	9.58 ± 0.37	11.75 ± 0.59	0.02
Hind leg	29.07 ± 0.30	30.99 ± 1.54	0.27
Third ribs	2.19 ± 0.03	2.65 ± 0.18	0.05
MLD area (cm^2)	8.66 ± 0.93	14.63 ± 0.92	0.05

Table 5. Means (±S.E.) of meat colour parameters for Saanen and Bornova kids during storage

Storage (day)	Colour parameters	Saanen (n = 5)	Bornova (n = 5)	P
1	L*	41.08 ± 0.51	41.39 ± 0.24	0.61
	a*	2.29 ± 0.45	2.18 ± 0.32	0.86
	b*	5.53 ± 0.38	5.75 ± 0.05	0.59
2	L*	43.29 ± 0.41	43.70 ± 0.27	0.44
	a*	4.30 ± 0.71	3.38 ± 0.24	0.26
	b*	8.19 ± 0.48	7.75 ± 0.09	0.40
3	L*	43.14 ± 0.30	42.75 ± 0.52	0.54
	a*	4.08 ± 0.22	4.28 ± 0.63	0.77
	b*	7.61 ± 0.18	8.25 ± 0.67	0.39
5	L*	40.78 ± 1.15	39.76 ± 1.05	0.54
	a*	5.17 ± 0.34	6.10 ± 0.71	0.28
	b*	7.82 ± 0.37	8.31 ± 0.32	0.36

colour did not show any significant differences between two types or genotypes of kids. Todaro *et al.* (2002) reported that the colour of meat is very important to evaluate the goat carcasses. Consumers prefer pale or pink meat. So that the meat colour of Saanen kids was paler than that of Bornova kids.

Saanen kids had meat of pale and pink colour, which is most acceptable to consumers. Lower L* values and higher a* value show darker muscle colour. For that reason the results can show that the shelf life of Saanen meat is longer than Bornova meat.

CONCLUSION

Although fattening performance under the intensive system was higher in Saanen kids, carcass weight and yield were higher in Bornova kids. The meat colour did not show any significant differences between the two breeds. But the meat of Saanen kids is most acceptable to consumers.

Acknowledgements

Financial assistance of the Commission for Ege University Scientific Research Projects is gratefully acknowledged.

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Received: 03–03–31
Accepted after corrections: 03–08–25

ABSTRAKT

Výkrmnost a jatečné vlastnosti kůzlat samčího pohlaví sánského plemene a plemene bornova při intenzivním způsobu odchovu

Byl proveden individuální výkrm dvaceti kůzlat sánského plemene (n = 10) a plemene bornova (n = 10) po dobu 56 dní při intenzivním způsobu odchovu. Byly hodnoceny tyto ukazatelé: výkrmnost, jatečné znaky a vlastnosti jatečného těla. Kůzlata sánského plemene měla ve srovnání s kůzlaty plemene bornova významně vyšší průměrný denní přírůstek (161,52 g vs. 132,05 g) a denní příjem koncentrovaného krmiva (851 g vs. 725 g) (P < 0,05). Jatečná výtěžnost za tepla byla významně vyšší (P < 0,05) u kůzlat plemene bornova než u kůzlat sánského plemene (55,19% vs. 52,20%). Mezi oběma plemeny byly zjištěny významné rozdíly (P < 0,05) také v podílech některých nejatečných partií. Rozdíly mezi tělesnými orgány a rozměry jatečného těla nebyly významné s výjimkou délky a šířky končetiny (P < 0,05). Obecně lze říci, že rozdíly v mase I. třídy nebyly u těchto plemen významné, ale kůzlata plemene bornova měla významně vyšší plochu MLD (P < 0,05). Kůzlata sánského plemene měla světlé maso růžové barvy, což je pro spotřebitele nejpřijatelnější.

Klíčová slova: kůzlata; výkrmnost; jatečné vlastnosti; kvalita masa

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The effect of sire line on learning and locomotor behaviour of heifers

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ABSTRACT: The aim of this study was to test the effect of sire line on maze learning ability and locomotor behaviour in open-field tests of heifers, consistency over the time of grid crossing and relationship between the time of traversing the maze and grid crossings in open-field tests, respectively. We analysed the results of ethological tests for 54 Holstein heifers that descended from 7 sires. Maze behaviour was observed at the age of 15 weeks, an open-field test was applied at two age periods, 16 weeks and 18 months. We found out highly significant differences in the time of traversing the maze between heifers of different sire origin ($P < 0.01$). The number of grid crossings over the five minutes of the open-field test did not differ between the daughters of the age of 16 weeks and 18 months. Repeatability between the number of grid crossings at the age of 16 weeks and 18 months was proved by significant correlation ($r = 0.2713^*$). On the contrary, significant relationships between the times of traversing the maze and locomotor behaviour in the open-field test ($r = -0.3739^*$) were found only when the sequence of observations followed after a week pause (age of 15 and 16 weeks).

Keywords: heifers; sire; maze; open-field test; repeatability; learning; locomotor behaviour relationship

The use of modern automatic housing and milking systems instead of conventional technology requires cows resistant to stress and able to adapt to altered conditions of environment in coherence with new procedures and methods of dairy management (automatised feeding, robotisation of milking). The individual reactions in various adverse situations can be used to predict the adaptability of animals to breeding technology.

Behavioural traits are largely determined by the environment, with little apparent genetic influence (Stricklin and Kautz-Scanavy, 1983/1984). Behaviour in an unknown environment is connected with temperament. This term has been of interest since the domestication of livestock. Cows were selected for docility through the ages (Dickson *et al.*, 1970). Hurnik *et al.* (1995) wrote that temperament is a simplified generalization of an organism according to its excitatory or inhibitory reactions, persistent habits, level of motor activity, emotionality, alertness and curiosity.

Temperament is measured in numerous, vastly different ways, as reviewed by Burrow (1997). In some methods the observer used predefined scores to indicate the overall level of emotionality. In other cases, the observer used a scaling technique to indicate to which temperamental trait an individual referred. But there is a certain risk of subjectivity. Although a subjective method to measure temperament can provide information on the individual responses, objective behavioural tests would facilitate the comparison of individuals in a standardised way (Manteca and Deag, 1993). However, it is possible that some tests that identify particular aspects of animal behaviour also have favourable correlations with other behavioural aspects. The open-field test previously used to measure "emotionality" in animals appears applicable also to "temperament" (Kilgour, 1975).

The ability of an animal to change its behaviour to cope better with environmental circumstances is due to a biological phenomenon called learning. The maze learning ability is a type of operating conditioning and can be called trial-and-error learning or instrumental learning. The behaviour is the instrument by which the reinforcement is obtained (Houpt, 1991). Genetic differences can affect the learning ability of different strains within a species.

The speed and correctness of an animal in running through various types of mazes was used as a measure of animal intelligence and learning ability for a long time (Albright and Arave, 1997).

What do the notions temperament and learning ability mean in dairy cattle? According to Albright and Arave (1997), the system of management under which cattle are raised and kept has a profound effect on their temperament. Handling problems are encountered with dairy cattle to a lesser degree than with beef cattle. However, if animals are kept in big herds on pasture, but also during the first milkings of first-calved cows, both the stockperson's safety and the animal's welfare can worsen. Reactions of animals could sometimes be dangerous. Therefore for the sake of the safety of dairymen it is very important to anticipate their unexpected changes of behaviour (Grandin and Deesing, 1998). Learning ability is of special interest to breeders. This form of associative learning in which several successive responses are associated with a reinforcer is involved in learning how to get from one place to another. Farm animals readily learn their way around the area available to them on farms so it is to be expected that they can learn to run mazes (Fraser and Broom, 1997). Dairy cattle must learn to cope with environments vastly different from the habitats to which their ancestors were adapted. Floors, partitions, noises, overcrowding, light, food and bedding are just a few of the unnatural environmental conditions imposed by domestication. According to Kratzer *et al.* (1977), the farm animals can probably be preconditioned to stressful situations. If such preconditioning to psychological stresses is to be economically achieved, farm animals must have the abilities to learn and remember.

Temperament of cattle is a moderately heritable trait in Holstein cows (Dickson *et al.*, 1970). *Bos indicus* breeds are more temperamental than *Bos taurus* (Burrow, 2001) when reared under comparable conditions. Flight speed scores were moderately to highly heritable (0.40–0.44). Genetic and phenotypic relationships between flight speed scores and most other traits indicated that, under extensive management systems, temperament is a largely independent trait (Burrow, 2001).

In experiments discussed in a review of Hohenboken (1987) with respect to breed differences in learning ability of pigs, estimated heritabilities of the measure of learning ability were 0.45 and 0.52. Results suggested that neither prenatal nor postnatal maternal effects nor dominance effects of genes were important determinants of avoidance learning behaviour. Arave *et al.* (1992) proved that Holstein heifers of some sires showed a higher level of activity and better ability to learn in the maze.

In the literature there is little evidence of a relationship between temperament and learning ability. Kratzer (1971) reported on the inheritance of learning ability in pigs, as assessed by avoidance behaviour, and on emotionality scores. Avoidance learning scores were estimated to have heritability of 0.31 while heritability of emotionality was only 0.10. In the experiment of Kilgour (1975), the cows were tested in an open-field arena for three days before the training trials of the maze test. The correlation of ambulation scores in the open-field test with total error scores in the maze test was positive and significant ($r = 0.45^{**}$), and similarly the ambulation score correlated with rapidity of learning score ($r = 0.54^{**}$) (Kilgour, 1981).

The genetic influences on behaviour can be clearly manifested by the study of influence of sires. The sire lineage influences a large part of the population so its genetic qualities are effective as a stabilization factor. The sire is effective in the herd during a relatively short period, so the complex of factors to which its daughters are exposed during rearing should not be of such variability (Kubek *et al.*, 2000; Rybanska and Strapakova, 2001). The entire adaptability of the population through the sires can be important.

Dickson *et al.* (1970) found out that father has a significant influence on behaviour of daughters in the milking parlour and on their temperament. They used 31 sires with five or more daughters. The estimates of heritability for adjusted dominance value and temperament score were 0.07 and 0.53, respectively. Sato *et al.* (1981) estimated heritability of temperament from the observed resemblance of daughters to their dams (0.67). Kovalcik *et al.* (1988) compared the behaviour of mothers and their daughters in open-field tests and they found out that the total time of motion was significantly longer in mothers, younger daughters had higher locomotor activity. Significant differences were found in the evaluation of four genetic sire lines (Kovalcikova *et al.*, 1988).

The aim of this study was to test three hypotheses: (a) The sire line of heifers influences their time of traversing the maze and number of crossed squares in open-field tests. (b) Will the locomotor behaviour measured by a number of crossed squares at the age of 16 weeks repeat at the age of 18 months?

(c) Is there any relationship between the time of traversing the maze and the number of crossed squares in the open-field test in heifers?

MATERIAL AND METHODS

We used 54 Holstein heifers. They were reared with mother until the seventh day and then in individual hutches till weaning. They were kept in loose housing in groups according to age after weaning. The heifers originated from 7 sires (BS-17, n = 5; BS-19, n = 11; BS-22, n = 15; CLE-15, n = 4; DIX-1, n = 9; KLK-2, n = 3; NEW-3, n = 5).

Behaviour was evaluated using maze and open-field test. We performed the maze learning ability tests with animals at the age of 15 weeks. The 6-unit maze (Figure 1) was constructed in a pen 16.4 × 4.5 m from steel fence 1.5 m high covered with a black plastic sheet. Five barriers were installed inside which marked the beginning and the end of the route and also particular parts of the maze. In the exit part a bucket with feed mixture was placed. Each calf was put to the maze entrance and the door was closed behind it. If the calf stood without movement in e some part longer than 3 minutes, it was forced gently to movement. The calf was allowed to eat for only a few seconds, whereupon it was led out of the maze to repeat the procedure. Time was recorded from the moment of the entry to the exit.

The calves had to solve two tasks on two consecutive days. On the first observation day (task A), the calves were tested five times, three runs in the morning and two runs in the afternoon. The first test was for training. On the second day (task B), there were two runs in the morning and two runs in the afternoon. In task A, the passage was open on the left side, and on the right side (task B) on the next day.

An open-field test was applied at two ages: A1 (16 weeks) and A2 (18 months) in an arena marked off into 9 squares. In A1, the size of arena was 4.5 × 4.5 m, at the A2 age 10 × 10 m. The calves were given one 5-min test (morning). The animals were exposed to isolation and silence. Behaviour was recorded by a video camera in both tests.

The data were analysed by a statistical package STATISTIX (Analytical Software, Tallahassee, USA). The normal distribution of data was evaluated by Wilk-Shapiro/Rankin Plot procedure. All data concerning the number of crossed squares conformed a normal distribution. Approximate Wilk-Shapiro normality statistics were 0.9444 for the age of 16 weeks and 0.9559 for the age of 18 months. However, in the assessment of times of maze traversing, one or a few points departing from the linear trend of the plot could indicate non-normality. Approximate Wilk-Shapiro normality statistics were also lower (0.7912 for task A and 0.8616 for task B). For this reason, the Kruskal-Wallis ANOVA procedure was more suitable for the comparison of groups. Significant differences between groups were tested by Comparisons of Mean Ranks. Spearman correlation was used for the evaluation of relationships between the time of traversing the maze and the number of grid crossings in the whole set of 54 heifers.

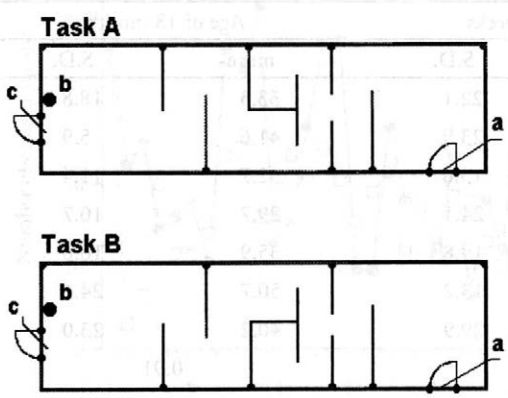

Figure 1. The maze for calves

a = enter; b = bucket with feed mixture; c = exit

RESULTS AND DISCUSSION

The aim of the present study was to objectively quantify the effect of sire line on learning ability and locomotor behaviour as a manifestation of the temperament of heifers, and the relationship between these behaviours and consistency over time, respectively. Therefore heifers of the same breed, age and reared under the same, controlled housing were used.

Maze learning and locomotion in open-field

During the first four tests, when the maze was opened to the left side, the fastest heifers were those

of sire D and the slowest those of sires E and F. The second day, after changing the configuration of the maze by opening a passage to the right side (task B), the times of traversing the maze increased in comparison with task A (Table 1). The previous trend was maintained, calves of sire D were traversing towards the goal the fastest and those of sires E and F the slowest. There were significant differences between daughters of the observed sires in both tasks ($P < 0.01$). According to an evaluation of the total time of traversing the maze in all eight tests, we can divide the heifers into two different groups – daughters of sires F, E and the others (daughters of sires C, G, A, B and D).

Our results proved highly significant differences between sires in learning ability of their daughters measured by the time of traversing the maze, similarly like in the paper of Arave *et al.* (1992). Studies of comparative intelligence can answer some questions about the role of particular learning abilities in the survival of a species. Dairy cattle can probably be preconditioned to stressful situations. If

Table 1. Times of traversing the maze (s)

Sir	*n*	Average of tests 1–4		Average of tests 5–8		Total time of tests 1–8	
		mean	S.D.	mean	S.D.	mean	S.D.
A	11	50.7	50.4	72.3	42.0	492.1	337.2
B	7	34.2	18.2	60.1	33.8	377.3	179.9
C	15	50.2	29.8	110.7	70.7	643.3	368.2
D	4	20.9	13.0	42.2	15.2	252.5	110.9
E	9	123.0	82.1	169.9	84.1	1171.4	469.6
F	3	110.7	88.4	199.2	149.2	1239.7	947.4
G	5	54.8	50.6	69.3	28.1	469.4	134.4
F-value		3.33**		3.41**		4.16**	
P		0.0081		0.0071		0.0054	
Significance between sires		N.S.		E : D*		E : B,D*	

DF = 53
S.D. = standard deviation of mean
*$P < 0.05$, **$P < 0.01$

Table 2. Number of grid-crossings during 5 minutes of open-field test

Sir	*n*	Age of 16 weeks		Age of 18 months	
		mean	S.D.	mean	S.D.
A	11	48.6	22.1	33.3	18.8
B	7	46.6	23.9	41.6	5.9
C	15	33.8	13.6	32.7	11.4
D	4	45.7	24.1	29.7	10.7
E	9	40.0	19.8	35.9	16.0
F	3	36.7	13.2	50.7	24.6
G	5	45.4	29.9	40.2	23.0
F-value		0.58		0.91	
P		0.7428		0.4993	

DF = 53
S.D. = standard deviation of mean

such preconditioning to psychological stresses is to be economically achieved, farm animals must have the abilities to learn and remember.

Locomotor behaviour in the open-field test did not differ between daughters of the observed sires at the age of 16 weeks (Table 2). Daughters of sire A crossed the most grids in 5 minutes of the test (48.6) and daughters of sire C the fewest (33.8). Similarly, at the age of 18 months, no significant difference between the groups of daughters in the number of grid crossings was found. The most grids were crossed by daughters of sire F (50.7) while daughters of sire D crossed the fewest grids (29.7).

Open-field tests are a method recommended to evaluate the temperament in animals and their ability to adapt to new unknown conditions (Kilgour, 1975; Manteca and Dough, 1993). We presume that it can be applied to a full extent only to animals that were reared on pasture or in extended pens of the feedlot type. Heifers used to regular treatment, manipulation and frequent displacements are temperate and cannot express their nature.

Burrow and Dillon (1997) suggested that operators could select potentially calm animals on the basis of their temperament before the entry to the feedlot to improve welfare and performance of the whole group. But our results obtained during observations in the open-field test did not confirm this hypothesis. The problem probably lies in a suitable method of testing because temperament is mostly determined as the animal's flight speed or the restraint test. It is also possible that the Holstein breed animals are not easy to evaluate because of their very docile temperament and discipline. As Burrow and Dillon (1997) wrote, there are great differences between temperament tests, scoring systems, species of livestock, previous handling experience and physical locations. An open-field test developed for laboratory animals was adapted for farm animals, but it is possible that we do not precisely distinguish the kind of motivation in cattle which is expressed by locomotor behaviour: fear, exploration or social motivation.

Consistency of locomotor behaviour over time

A positive correlation (r = 0.2713*) between numbers of grid crossings at the age of 16 weeks and 18 months suggested that repeatability of locomotor behaviour in the open-field test existed also 14 months later. Graphic comparison of locomotor behaviour is in Figure 2. Similar findings were also mentioned by Kovalcikova and Kovalcik (1987), who compared the total time of movement in heifers at the age of 3 and 18 months (r = 0.490**), and Jensen *et al.* (1999) during the evaluation of the number of entered squares in calves 2 and 10 weeks old (r = 0.40***). We presume that the shorter the

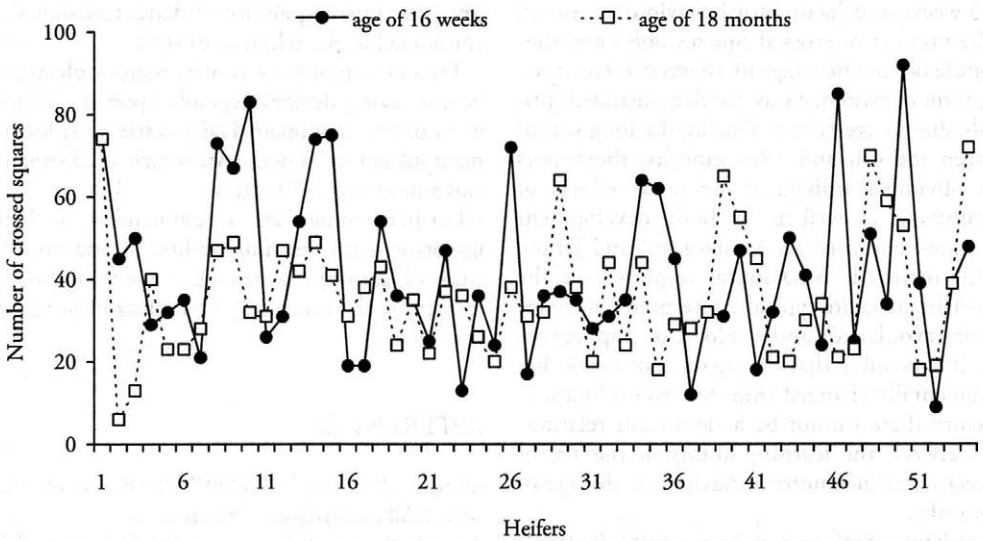

Figure 2. Locomotor behaviour in open-field tests at the age of 16 weeks and 18 months

period between observations, the higher the repeatability. The results of Bünger and Kaphengst (1987) suggested it as well. They repeated open-field tests after a period of 2 hours to 29 days in calves. The highest repeatability was found in the period testing 2 hours to 36 hours ($r = -0.972^{***}$) compared to periods 2 days to 13 days ($r = -0.527^{***}$) or 14 days to 29 days ($r = -0.687^{***}$).

Relationship between the time of traversing the maze and number of grid crossings

The results of testing of the hypothesis about the relationship between maze behaviour and ambulation in an open-field test are listed in Table 3. The relationships between these behaviours changed as the heifers aged.

Table 3. Correlations between the time of traversing the maze and number of grid crossings

Time	Grid crossings	
	age of 16 weeks	age of 18 months
Task A	–0.4092*	–0.0180
Task B	–0.3173*	–0.0265
Task A + B	–0.3739*	0.0063

Significant relationships were found only between the times of traversing the maze at the age of 15 weeks and locomotor behaviour measured by the number of crossed squares one week after the maze observation (age of 16 weeks). However, long-term consistency was not demonstrated, primarily due to age effects. During the long period between the 4th and 18th months, the heifers were obviously influenced by many effects of environment as well as by body development and sexual maturity. As Munksgaard and Jensen (1996) reported, behavioural responses in the open-field arena are typically interpreted in terms of fear (avoidance) and exploration (approaching). It is possible that dominant motivation has fundamentally changed from fear to exploration, therefore there cannot be a significant relationship between the learning ability at the age of 15 weeks and locomotor behaviour at the age of 18 months.

Correlation coefficients were negative (–0.4092*; 0.3173*; –0.3739*), which indicates that the heifers that resolved the maze faster were more lively in the open-field test. This could suggest that the animals that are more lively (in conception Burrow (1997) and the others with worse, poor or bad temperament) have a higher learning capacity in the maze and can be suitable for modern systems of management. This leads to a generally presented opinion that the individuals which orientate themselves quickly and behave calmly during the open-field tests will react calmly in other non-model situations which arise during their life.

In further research it could be very useful to evaluate also a relationship between mothers and daughters. Calf can learn a part of temperament by conscious or unconscious imitation of its dam rather than inherit the propensity for a certain temperament from both parents. The difference between heritability estimated from daughter-dam resemblance and heritability estimated from paternal resemblance can reflect behavioural tendencies learned by daughters from their dams (Hohenboken, 1987).

CONCLUSIONS

We studied the behaviour of 54 heifers of Holstein breed in a maze (age 15 weeks), and in open-field tests (age 16 weeks and 18 months) in dependence on their sire. However, we did not obtain any sufficient proofs about behaviour in open-field tests. The analyses showed that the sire line influences only the time of traversing the maze. Thus the learning ability of daughters should be considered in the selection of sires.

The development of future, more sophisticated labour-saving devices depends upon the abilities of future farm animals. Dairy cattle must learn to manipulate mechanical devices such as self-waterers and automated self-feeders.

Further studies are recommended to better understand the learning ability. In addition, the study of learning can be used as a new approach to investigate the processes of handling in progressed management.

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Received: 03–02–03
Accepted after corrections: 03–09–01

ABSTRAKT

Vliv původu po otci na učení a pohybové chování jalovic

Cílem studie bylo testovat vliv původu jalovic po otci na jejich schopnost učení a pohybové chování v open-field testech, opakovatelnost přechodu čtverců a vztah mezi časem přeběhnutí bludiště a počtem přechodu čtverců v testech open-field. Analyzovali jsme výsledky etologických testů 54 jalovic holštýnského plemene, které pocházely po

sedmi otcích. Bludišťové chování bylo sledované ve věku 15 týdnů, open-field test byl aplikován ve dvou věkových obdobích, v 16 týdnech a 18 měsících. Zjistili jsme vysoko průkazné rozdíly mezi skupinami dcer býků v čase přeběhnutí bludiště ($P < 0.01$). Počet přechodů čtverců za pět minut open-field testů se statisticky mezi dcerami sledovaných otců nelišil ani ve věku 16 týdnů, ani 18 měsíců. Opakovatelnost mezi počty překročených čtverců ve věku 16 týdnů a 18 měsíců byla dokázána signifikantní korelací ($r = 0.2713^*$). Naopak, signifikantní vztahy mezi časy přeběhnutí bludiště a pohybovým chováním v open-field testu ($r = -0.3739^*$) se zjistily jen v případě sledování následujících za sebou po přestávce dlouhé jeden týden (věk 15 a 16 týdnů).

Klíčová slova: jalovice; plemeník; bludiště; open-field test; opakovatelnost; vztah učení a pohybového chování

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An international scientific journal
published under the auspices of the Czech Academy of Agricultural Sciences
and financed by the Ministry of Agriculture of the Czech Republic

Czech Journal of Animal Science (Živočišná výroba) • Published by Czech Academy of Agricultural Sciences – Institute of Agricultural and Food Information • Editor Office: Slezská 7, 120 56 Praha 2, Czech Republic, phone: + 420 227 010 352, fax: + 420 227 010 116, e-mail: edit@uzpi.cz •

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